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"WHEN WORLDS COLLIDE"

REVIEWED BY A. C. CLARKE

The well-deserved success of *Destination Moon* made the news that the George Pal—Chesley Bonestell partnership was working on further interplanetary films all the more welcome. It is with considerable regret that we must record our disappointment with their second offering, *When Worlds Collide*.

Perhaps one should make clear at once the difference between the two films. *Destination Moon* was a straight "documentary" of the first lunar flight. It was not concerned with any other plot elements, was devoid of romance, and the characters were of secondary importance.

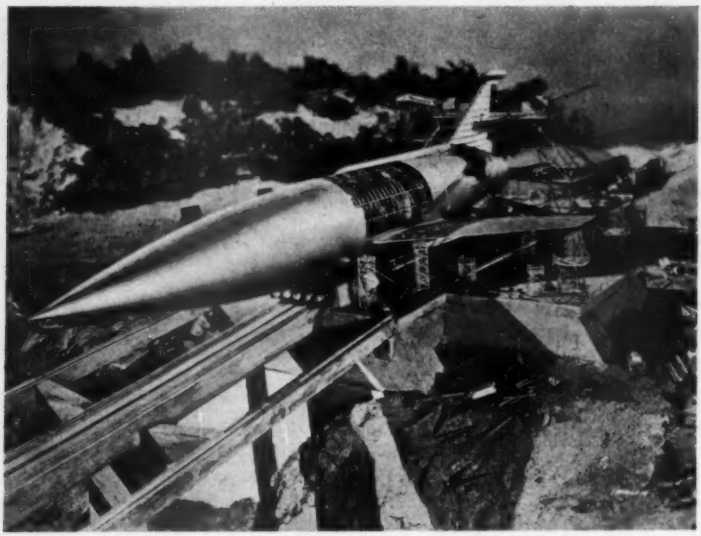
When Worlds Collide, based on the 1932 Balmer and Wylie novel of the same title, is concerned with a far greater theme—nothing less than the end of the world and the migration of a few survivors to another planet. It has a number of well-defined characters and a good deal of love interest. Yet although the film contains moments of great excitement and never fails to hold interest, the final effect is one of anticlimax. This is largely owing to a script of a naïvete unusual even for Hollywood.

The story is simple enough—a dying sun enters the Solar System on a course that will eventually cause a collision with Earth. It has a single planet, and the only hope of mankind is that spaceships can be constructed in the eight (!) months before the collision, to travel to the solitary planet of the invading star.

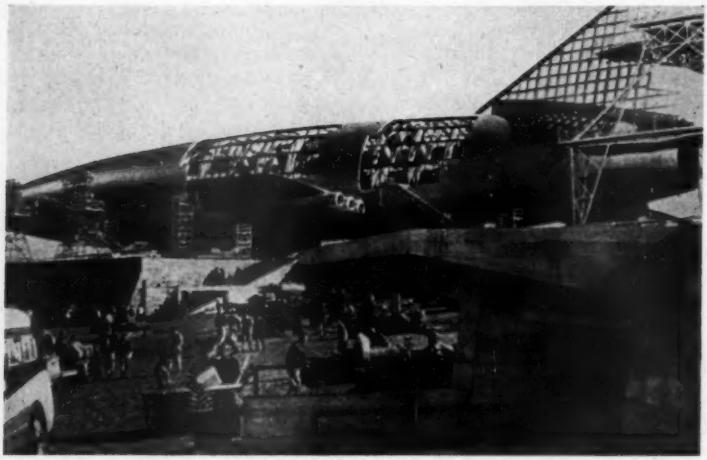
The sequences showing the building of the spaceship are excellently done and we must give Chesley Bonestell and George Pal full marks for these. The take-off is from a long ramp which, for some unexplained reason, dips down into a valley and then goes up the side of a mountain. (The only effect of such a dip, of course, would be to waste a certain amount of gravitational energy.) The ship itself is winged, so that it can make an atmospheric landing on the new planet—which for some reason has had its name changed from the book's sensible "Bronson Beta" to "Zyra."

Some of the scenes of destruction on the first approach of the invaders are superbly done—genuine disasters being skilfully combined with model work to produce a really terrifying sequence. The take-off is also very well contrived, and one of the moments which lives in the memory is the last view of the launching site, bathed in a ghastly yellow light from the star which now fills the sky.

By keeping the travellers in this interplanetary Noah's Ark strapped in



Spaceship under construction on the Launching Ramp.



Building the Spaceship.

Two scenes from *When Worlds Collide*, reproduced by permission of Paramount Picture Corporation.

their seats, the producer neatly avoids grappling with the problem of weightlessness. ("Zyra" is apparently so close that the whole voyage only lasts an hour or so.) The landing among the mountains of the new world, on a convenient snow-field, is dramatic enough, but what should be the big moment of the film is completely ruined. When the door of the spaceship is flung open (as someone rightly says: "Why test the air? We've nowhere else to go!") the snow has mysteriously vanished and we are confronted with a crude backcloth which is more like off-colour Disney than vintage Bonestell.

Since the film does not attempt technical accuracy on the scale of *Destination Moon* it is unfair to make detailed criticism of it on this score. One would, however, have imagined that it was obvious even to the most unscientific that the first spaceship could hardly be built from scratch in a fraction of the time necessary to design and construct a perfectly conventional airplane—especially when civilisation was collapsing on all sides. One also wonders what the average picture-goer will think of astronomical accuracy when he sees one group of astronomers, equipped with differential analysers and all modern conveniences, producing a prediction which is flatly denied by another group who presumably have the same facilities. (To anyone who remarks that astronomers are *always* disagreeing, and points to Fred Hoyle in proof, we would testily reply that there is not much room for argument over a simple problem in celestial mechanics.)

On balance, *When Worlds Collide* certainly contains enough interesting material to make it worth a visit. Whether any producer of lesser genius than D. W. Griffiths could have handled this theme properly is a subject on which everyone will have their own opinion.

HAYDEN PLANETARIUM SYMPOSIUM ON SPACE TRAVEL

On October 12, 1951, the Hayden Planetarium in New York held an astronautical symposium at which six short papers were read by leading authorities in their respective fields. The proceedings occupied the morning and were followed by a luncheon and open discussion.

The programme began with some opening remarks by Dr. Albert E. Parr, the Director of the American Museum of Natural History—the Hayden Planetarium is attached to this institution at Central Park (N.Y.) which is closely analogous to our Science, Natural History, and Geological Museums in South Kensington. He was followed by the Chairman of the Planetarium and Department of Astronomy, Mr. Robert E. Coles, who spoke of the work of his section and the relevance to it of the new subject of astronautics. In his talk (entitled *The Conquest of Space*), Mr. Coles said: ". . . the Hayden Planetarium has chosen the day which commemorates Christopher Columbus, that outstanding conqueror of space on earth, for this symposium on interplanetary space travel," and indicated that it was the intention to make such meetings an annual event. He then used the Planetarium projector to take his audience on a short imaginary visit to Mars.

The Co-ordinator of the Symposium was Willy Ley, who spoke next on

Thirty Years of Space Travel Research. After outlining the history of the subject (which he said covered only the last 30–35 years, if one neglected the "pre-history"), Mr. Ley stressed the importance of the orbital rocket, both in its own right and as a necessary first stage in the development of orbital refuelling techniques for interplanetary spaceships. He said: "I believe that a small and unmanned orbital rocket is possible in present-day rocket engineering. It would be a rather big project, but a possible one."

Ley was followed by Robert P. Haviland, a research engineer of the General Electric Company's "Project Hermes." Originally billed to speak on *The Engineering and Application of the Satellite Vehicle*, Mr. Haviland (according to newspaper reports) was requested by his firm to change his subject, as they considered the original choice premature and inopportune; he finally gave a talk entitled *Report on the Bumper Programme.* This dealt with the firings of the 2-step V.2/WAC Corporal rockets, with which development he had been closely associated; in view of its particular interest, his paper is reproduced in full at the end of these notes.

Because it also has a special interest, raising as it does a number of points which the world at large would no doubt consider revolutionary, we have also printed in full the concluding paper of the Symposium. This was *Legal Aspects of Space Travel*, and was given by the Deputy Director of the General Legal Division of the United Nations Legal Department, Mr. Oscar Schachter. Older members of the B.I.S. will remember that similar ideas were briefly discussed in the classic essay, *The Challenge of the Spaceship*, by our present Chairman in 1946 (*J.B.I.S.*, Vol. 6, No. 3).

In between those of Haviland and Schachter, two other interesting papers were presented: *The Upper Atmosphere and "Empty" Space*, by Dr. Fred L. Whipple (Chairman of the Department of Astronomy of Harvard University), and *Man in Space*, by Dr. Heinz Haber (of the Department of Space Medicine at the U.S.A.F. School of Aviation Medicine, Randolph Field, Texas).

Dr. Whipple discussed current knowledge and research on such subjects as air density in the extreme upper atmosphere and meteor intensity in outer space. He thought that a spaceship would have a good chance of surviving the risk of damage by meteors, at least if it avoided the known large meteor streams, and especially if its hull were fitted with a thin outer shield (or "bumper") to explode any incident meteoric bodies and so reduce their penetrating power. His views on the feasibility of aerodynamic braking, for landing returning spaceships on Earth, were, however, at variance with other recent pronouncements on the subject. Dr. Whipple said: "Winged space vessels attempting to soar to the surface of the earth would melt away inches of their front surfaces. Only a reversed rocket technique, with all of its expense in power and weight, appears feasible as a means for landing finite masses on the earth from space." (*Cf.* Nonweiler, *J.B.I.S.*, Vol. 10, Nos. 1 and 6.) Even on the subject of the meteor danger, Dr. Whipple uttered a note of caution as regards very small meteorites: "Very probably," he said, "there are many more than we think!"

Dr. Haber spoke of the problems of air-conditioning, weightlessness, and exposure to cosmic radiation, which would be encountered in any project for

manned space-flight. He pointed out that such problems were not so peculiar to astronautics as might be thought, since we were being, as it were, gradually introduced to them by the experiences of the crews of modern very high performance aircraft. Aviation medicine, in fact, was merging imperceptibly into "space medicine"; he stressed the importance of the latter subject, since: "In view of the tremendous expenditure required to approach space, it would be foolish to jeopardize the possible success of a flawless machine by human failure. The physiological and psychological properties of man are integral structural parts of a spaceship." Of the most serious problems raised by these considerations, Dr. Haber went on to say:—"If it comes to discussing the possible biological effects and the hazards to health arising from cosmic rays, we are entering a still highly controversial field. Certainly, at sea level, no such hazard exists. On the contrary, the question has been raised if a natural background of penetrating radiation might not play a basic role for the evolution and maintenance of life. However, a number of fast moving particles of the higher layers of the atmosphere strongly suggest that a certain hazard from cosmic radiation might exist. This assumption is the more suggestive, if the newly discovered heavy primaries of cosmic radiation are taken into account.

"The heavy primaries were discovered by the extremely strong and heavy tracks they had left in the emulsions in photographic plates taken aloft by means of balloons. These particles range in atomic weight between 4 and 60 and more. They are endowed with tremendous energies millions of times greater than those that can be produced in the laboratory. These particles quickly dissipate their energy when transversing the highest layers of the terrestrial atmosphere. The atmospheric filter is so effective that no such high-energy particle has been found below an altitude of 70,000 feet, while their number increases substantially above that level.

"Apparently, a metal shield equivalent in thickness to the rest of the atmosphere above 70,000 feet would absorb the original heavy primaries entirely. To this end, a wall consisting of steel would have to be at least two inches thick. Such a wall is entirely out of the question in the construction of a ship where conserving weight is the basic rule.

"Obviously then, a certain part of the energy of the heavy primaries will have to be absorbed by the passengers of a spaceship. In ploughing through the living tissue, the particles quickly dissipate the rest of their energy by forming an extremely concentrated streak of ion pairs along their tracks. A certain amount of damage to the living cell must, by necessity, be anticipated.

"In view of this bleak picture one may better resolve to call off space flight and stay behind the powerful shield of the homely atmosphere. This, in turn, would be a gross exaggeration of the situation. It has been estimated that, at an altitude of 80,000 feet, an unprotected individual would absorb radiation at a rate of about 25 times greater than the permissible weekly dose. Since this latter rate is considered harmless even if administered indefinitely, short trips into space will most probably be safe. However, if radiation effects are allowed to accumulate over the weeks and months of an extended trip through space, the hazards arising from cosmic radiation may indeed become a serious problem.

"It is a matter of common knowledge that elimination of gravity—in other words weightlessness—with all its unique consequences, will take place during a flight in space. This effect is not produced by the decrease of terrestrial gravitation with increasing altitude, as one might be led to believe. The phenomenon of weightlessness is a consequence of the accelerated motion to which the ship will be subjected as soon as it is able to yield freely to the gravitational pull of the earth. The ship will then fall freely or follow an elliptical trajectory depending on the initial characteristics of motion. The motion in a free fall or along a cosmic trajectory, however, entails high velocities, and these speeds, in turn, require comparative freedom from friction. In other words, an aircraft capable of outclimbing the denser layers of the atmosphere and of cruising at high velocities, is gradually beginning to change from an ordinary means of transportation to a celestial body for short periods of time. Where, the frictional forces from the atmosphere wane, the domain of weightlessness begins, and the pilots of modern high-altitude, high-velocity aircraft begin to experience reduction or lack of body weight in certain flight manoeuvres. The durations of these states of reduced or eliminated weight are still short—one-half to one minute at the most—but weightlessness in aviation is here to stay. The answer to the question "How does man react to the destitution of his weight?" is of no less importance to the aircraft designer of to-day as it is to the planners of space flight.

"Gravity as a physical factor of environment has the outstanding property of being omnipresent and everlasting. Life has developed under its incessant presence. Not a single individual has as yet been away from its influence for more than a few seconds. So our experimental knowledge concerning the possible effects of weightlessness of man is rather sketchy. But a detailed analysis of the bodily functions in relation to gravity makes it possible to hazard an intelligible guess of what to expect under conditions of zero-gravity.

"With the destitution of his weight man gets the impression that every kind of support gives way under him. His first reaction to this experience will be rather inevitable. He will, upon sudden deprivation of support, grasp for hold in a violent reaction. Any effort to gain support, however, will fail in contrast to comparable common experience. The sensation of falling into a bottomless pit will go on, no matter how fast one holds. One may count on a gradual adaptation to the feeling associated with this perpetual fall after the first shock has worn out. A sudden transfer into the gravity-free state is most certainly no thrill for weak souls.

"It is not necessary to anticipate any serious difficulties in the functions of blood circulation and breathing during weightlessness. These operate chiefly under the muscle force of the heart, the elastic forces of the blood vessels, the midriff, and the chest. Weight of the blood plays a noticeable, yet dispensable part in circulation. Breathing is affected by differences in pressure between the ambient air and the air inside the lungs. The pressure differences are brought forth by the action of the body regardless of the air's weight. It is the nervous system of man, his sense organs and his mind, that are likely to cause trouble.

"In speaking of gravity acting on and within the human body, one must

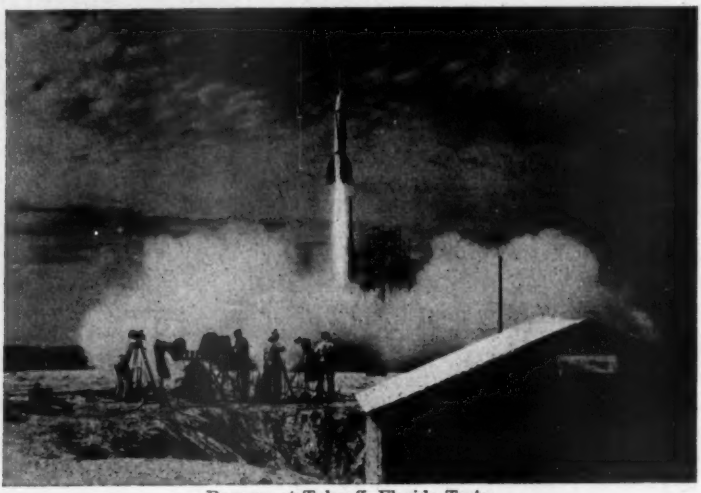
be aware that man possesses an intricate system of so-called mechano-receptors which provide detailed information of all kinds of mechanical stimulation. Among the mechano-receptors we discern: (1) the vestibular apparatus of the inner ear which contains the receptor organs for rotatory and translatory motion; (2) the tango-receptors of the pressure sense of the skin; (3) the muscle spindles which are imbedded in all those muscles that fix and move bodily masses; (4) the corpuscles named after their discoverers Vater and Pacini. These corpuscles are found throughout the connective tissue, especially near the muscles. Since their pattern of stimulation provides information of the posture of the body's parts, man is fitted out with a special posture sense. The last three senses form a functional co-operative union controlling the perception of position, of active and passive movements of the body parts. In general, the excitation of the mechano-receptors does not fully reach consciousness in all cases. Their function is closely linked to a complicated reflex mechanism which serves to maintain equilibrium and to exercise bodily movements properly.

"The harmonious union of the various sense-modalities controlling the body movements is seriously disturbed by the lack of gravity. If the space traveller attempts to move inside the cabin, the utmost of care is indicated. The force of our muscles is adapted to the natural body weight. Each movement carried out with normal effort of the limbs, jerks the space traveller across the cabin. The proper use of the limbs must be learned; it must be in proportion to the inertia of the body's mass. Here, on earth, the weight of the arm, for instance, is reckoned with automatically every time we move it, while during weightlessness only the inertia of the arm must be overcome. The elimination of the body weight shifts the function of the power-sense to an entirely different level, because, for instance, it requires less effort to lift an arm. Thus, as a limb is moved, the power-sense has to adapt itself to an entirely different pattern of forces.

"Owing to the nature of their excitation, the receptors of the posture sense are hardly affected by the lack of weight. The function of the posture sense will not alter materially, since it gives notice of the various positions of the limbs independent of any outer force. Consequently, the perceptions stemming from the sense of power and posture fail to match under gravity-free conditions.

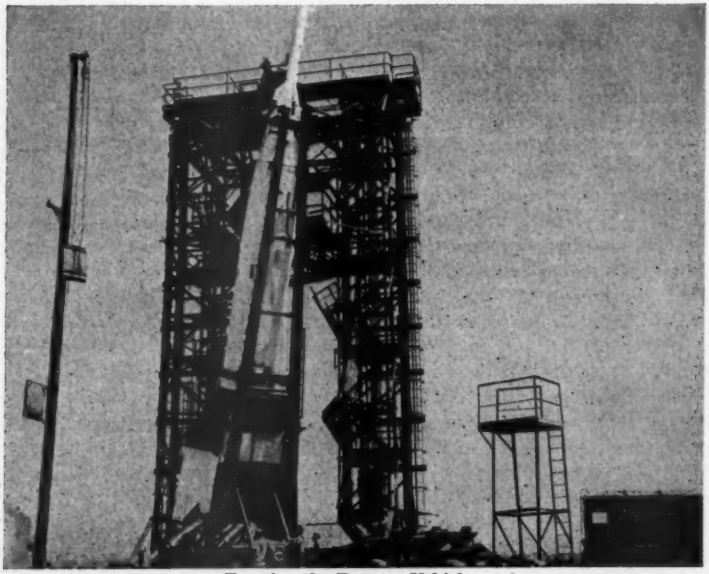
"The mechano-receptors take part in another important psycho-physical function, namely, orientation.

"In the presence of gravity, orientation is accomplished by registering the direction of gravity in relation to the body's position, while the eyes establish the position of the body relative to the objects around us. Both perceptions naturally match. In the state of weightlessness the mechano-receptors participating in orientation, fall short. Only the function of the visual organ stays the same; weightlessness has no influence upon it. But orientation can possibly be accomplished solely by means of the eyes. Experiences made in the learning process of blind flying indicate that man is capable of suppressing false information arising from his system of mechano-receptors. A pilot who flies through a solid overcast relies wholely on visual cues from his instruments. Through these alone he establishes orientation of his position and that of his plane in space. The mechano-receptors are inactive in a weightless body at



Bumper at Takeoff, Florida Tests.

About three seconds after takeoff the vehicle is climbing vertically. A paper covered pine control station protected by a sand wall appears in the foreground.



Erecting the Bumper Vehicle.

The combined vehicle is raised to the verticle by the German Meillerwagen. The gantry crane is then positioned around the vehicle to provide access to the various working levels.

rest. They will be stimulated, however, by every movement of the body. During these movements, the forces of inertia lend weight to the body in proportion to the acceleration and deceleration applied. It will be inevitable that the mechano-receptors will be placed under stimulations that vary greatly as to direction and size. At the same time, the eyes register an entirely different picture of the situation.

"Here again we experience a dissociation of the various qualities and modalities of perception and sensation, which, under the perpetual influence of gravity here on earth, are linked together closely. This phenomenon of dissociation will characterize the state of weightlessness.

"Recent investigations have revealed that certain forms of seasickness can be induced by a disharmony of the complex of perception and sensation. We can, therefore, not exclude the possibility that weightlessness is followed by a kind of "space-sickness" which would easily incapacitate the crew of a spaceship.

"Weightlessness will hardly be accompanied by an agreeable and welcome feeling of alleviation. It will not be an animating poise, discharged from the shackles of gravity. On the contrary, it is most probably a state of considerable physiological and psychological tension. It may be a painful lesson before the body and its movements can properly be controlled in the state of weightlessness. On the other hand, man has an astonishing ability of adapting himself to extreme conditions. He may even get used to the destitution of of his weight."

A REPORT ON THE BUMPER PROGRAMME

By Robert P. Haviland*

One of the objectives of rocket research and development is the attainment of greater altitude and range. This objective can be approached in several ways, one of which is the multi-stage rocket. The principles of the step rocket are well described in the literature, and a number of designs such as the Navy's "Aerobee" have used a very simple version of the principle. However, in these designs the first stage is of rather low performance, and is properly regarded and termed a booster.

In an effort to more nearly realize the full advantage of a multi-stage design, in 1946 the Army Ordnance Department decided to embark on a programme of design and development of a two stage vehicle of better performance than any vehicle then available. Since funds for rocket development were quite limited at this time, it was decided that the design would necessarily be based on available single stage vehicles.

The vehicles selected were the American WAC Corporal for the second stage, and the German A-4 (V-2) for the first stage. A co-operative programme called "Bumper" was established among the agencies responsible for various phases of the basic programme. These included:

The White Sands Proving Ground;
The Douglas Aircraft Company;

* *A paper read at the Hayden Planetarium Symposium on Space Travel.*

The Jet Propulsion Laboratory of the California Institute of Technology;
The Ballistic Research Laboratory of the Aberdeen Proving Ground;
The Hermes Project of the General Electric Company.

Basic responsibility for the programme was assigned to Project Hermes.

Design Considerations

It is quite easy to show, as is done in the literature, that ideal performance of multi-stage vehicles is secured if:

(1) The burnout weights of each stage form a geometric progression.
(2) The burning period of each stage commences immediately upon cessation of burning of the preceding stage.

Since economy had dictated that existing designs were to be used, it was not possible to optimize the staging. This left the problem sometimes known as "Condensation of the burning period" to be solved.

Ideally, the proper procedure calls for the second stage to be started at full thrust the instant the fuel of the first stage is exhausted. In practice this cannot be done. The most important limiting factor is the fact that a finite time, on the order of a half second, is required to start or stop a rocket motor. Also, to allow for variations in fuel flow rates, it is desirable that separation be initiated with a reasonable fuel reserve.

Several practical considerations affect the separation sequence. For example, if the first stage were shut off completely before attempting to start the second stage, drag forces would cause the fuel in the second stage tanks to move forward, uncovering the fuel outlets, causing a misfire. On the other hand, if the second stage were started early, the high acceleration of the first stage might prevent the separation. This would result in severe damage from the second stage jet.

Closely associated with this problem of the starting sequence is the actual design of the separation mechanism. This must be capable of supporting the second stage at high acceleration. Fairly large lateral forces may be present, particularly around sonic velocity, where aerodynamic stability is generally low. A reasonable degree of rigidity is required, to prevent aerodynamic effects causing loss of control. Finally, the actual separation must be allowed to occur freely.

Unfortunately, it is not possible to discuss the solution to these problems at this time. It may be noted, however, that published photographs clearly show that the combined vehicle used the classical configuration, with the second stage carried at the nose of the first stage, at the location normally used for payload.

A major problem which arose during the design was the matter of dispersion. At the time the programme was started the only available range was the White Sands Proving Ground, in southern New Mexico. This is an enormous place, roughly 40 miles wide and 120 miles long, with an area in excess of two million acres. However, as seen from the 250 mile peak altitude of the Bumper vehicle it bcomes a rather small target.

Analysis of the various factors influencing dispersion showed that the

most important errors would be those introduced during the first stage burning. Therefore, two new safety systems were developed for use at the proving ground. Both of these used velocity data, one derived from optical information, the other from differentiated radar position data. These, combined with earlier devices gave adequate safety assurance. Also, American built control system components were available by the time tests started. These proved to be so reliable that none of the Bumper tests were lost due to control failure.

One factor which had been almost negligible in all previous test work became extremely important in the Bumper programme. This was the rotation of the earth. The major component of the resulting Coriolis acceleration caused a westward displacement of the predicted impact point which amounted to about 15 miles, as compared to a non-rotating earth. To correct for this the line of flight at takeoff was rotated eastwards by nearly 10° for the high altitude trajectory. The remaining components of the Coriolis acceleration were neglected.

Instrumentation

Since the takeoff weight of the second stage was less than half of the one ton design payload of the V-2, there was almost no limit to the possible first stage instrumentation. For the second stage, however, the payload was limited to 50 pounds. It was considered essential that this payload include both a data gathering and a data transmission system, since the possibility of equipment recovery appeared to be extremely small.

Since this was a vehicle development programme it was decided to concentrate the instrumentation on performance data. After a survey of several possible solutions, a frequency doubling Doppler receiver-transmitter system was adopted as the basic second stage instrumentation. This had the advantage of providing velocity data directly, with position and acceleration being obtained by integration and differentation. Such data as burning time, time to peak, roll rate, and a few other items could also be obtained from the records. A further advantage of this system was the fact that adequate ground equipment was already available at WSPG.

The estimated weight of this system was somewhat less than the allowable payload. This permitted the addition of a newly designed, but somewhat rudimentary telemetry system, formed by impressing amplitude modulated signals on the output of the doppler transmitter. This was used to permit measurement of such quantities as skin temperature, impact pressure, and received doppler signal strength.

For simplicity, instrumentation for the first stage was limited to a radar beacon for position data, and a telemetry system which transmitted data on performance and on the separation sequence. The systems used were the same as those used for other V-2 operations at the White Sands Proving Ground.

Test Operations

In addition to an extensive static test programme it was considered necessary to check out some of the new techniques in flight before attempting to secure maximum performance. This was accomplished by limiting perform-

ance at the start of the programme to a value which would approximate that obtained from the V-2 alone. As the programme progressed, performance was increased to the maximum possible.

In all of these tests altitude was the primary consideration. While it would also have been interesting to have conducted tests for maximum range, this would not have provided appreciable additional data. Instead, two of the vehicles were expended in very low trajectory tests, to provide aerodynamic data not obtainable from wind tunnels.

A number of problems arose in connection with the test operations. One of these was the sheer size of the Bumper vehicle, which towered over 60 feet into the air. Its height prevented the use of the usual access platforms on the Gantry crane at White Sands. Therefore, an extensive system of outrigger platforms was attached to the gantry, to provide access to the upper working levels and special stands were built up for the levels nearer the ground.

Surprisingly perhaps, the actual handling of the vehicle did not prove to be a very serious problem. This was largely because the separation system was intentionally over designed, so that it would withstand in excess of 1g of lateral acceleration. This permitted use of the German Meillerwagen to handle the combined vehicle as was normal for the V-2.

The scheduling of operations did cause some trouble. It seems that every design has a number of operations which must be done last. For the Bumper these "lasts" consumed a total of four hours. While considerable use was made of previous experience, the first test was delayed about a half hour by accumulated schedule errors. As with everything else practice helped, however, and it was possible to advance the takeoff time on the last test by 15 minutes.

Because the Long Range Proving Ground, Florida, was a new base and had never before been used for operations of this kind, a number of operational problems arose there which were absent at White Sands. Some of the major items which had to be provided or improvised for these tests were: an equivalent to the WSPG gantry crane, launching pad and blockhouse; radar, Doppler, and optical stations; communications; assembly and storage areas, and many others. Even a simple matter, such as a road to the launching pad was the source of considerable trouble.

Some of the solutions were fairly primitive. For example, blockhouse walls of 1-inch pine do not inspire nearly as much confidence as does 8 feet of concrete!

The fact that these troubles were overcome was due to the unceasing efforts of all personnel concerned. In fact, these tests represented an inspiring example of the splendid co-operation between the Army, Navy, Air Force, and civilian agencies.

Tests Results

A total of eight Bumper vehicles were constructed and have been expended in test. Six of these were launched at the White Sands Proving Ground, and the remaining two at the Long Range Proving Ground. Not all of the tests were successful, but in only two cases did failure occur at such an early period that no significant data were obtained.

In the WSPG tests the maximum flight times from takeoff to impact were roughly 300 seconds for the first stage, and roughly 700 seconds for the second. It should be noted that the peak altitude and range of the V-2 are somewhat more than one-fourth of the corresponding values for the second stage. This shows that staging was not optimum, since ideally the values would have a ratio of one to four.

In the LRPG tests the vehicle was turned through a considerably larger angle than for the normal long range trajectory. This yielded a very low altitude trajectory and drag was very important. Since the Ballistic coefficient of the second stage is much poorer than for the first, the peak altitude and range ratios are still further reduced from the ideal values.

Most interesting of the tests was the launching of February 24, 1949, which established new altitude and velocity records. Some months after this test the second stage impact point was located. From the description of the area it appears that the vehicle fell in a flat spin, so that the impact velocity was very low. As a result recovery was surprisingly good. One of the most interesting features of the recovery was the erosion due to the very high stagnation temperature encountered in the flight.

Summarizing the results which have been released so far, the Bumper programme has:

(1) demonstrated the techniques of launching large two-stage vehicles and of securing separation at high velocities and altitudes;
(2) established a new velocity record of 7,550 feet per second, or 5,150 miles per hour;
(3) established a new altitude record of 250 miles above the earth; and
(4) demonstrated two-way communication with an object 250 miles above the earth, this being above the D, E and F layers of the ionosphere.

The costs of this programme were surprisingly low, since existing designs, components and instruments were used. Aside from the significant results which were obtained, it is believed that the costs were easily justified on the basis of the operational experience gained by the participating agencies. However, the results and the fact that the records established will stand for a long time are a source of great satisfaction to those who planned and participated in the experiments.

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LEGAL ASPECTS OF SPACE TRAVEL

By Oscar Schachter*

No doubt a lawyer will seem out of place in the discussion of celestial problems but unfortunately, as in other cases, he seems to be a necessary evil. For the conquest of space presents a number of inescapable legal questions, particularly in the field of international law. How far upwards does national sovereignty extend? To what extent will individual states be allowed to pre-empt the space above their territory and to stake out claims to the moon and other celestial objects? Will a satellite ship be legally free to conduct military operations? Will individual governments have the right to exclude others from the moon on the basis of discovery and control? These questions are not far fetched. They may well become practical issues within the next few years.

How far up does the territory of a state extend?

In ancient Roman law the landowner was deemed to own the space above up to the heavens. But this notion has long been abandoned in regard to private landowners. To-day, the private landowner no more owns all the air above him than a shoreowner owns all the sea before him. However, in international law it is well established that national states do have sovereignty over the airspace above their territories. It should be noted that the term "air space" has been used. In other words, the presently accepted rule of international law (as expressed in various multilateral treaties) is that the territory of the national state extends upward at least as far above the surface as to include the region which contains air. There is, however, no presently accepted rule of international law as to whether the space above and beyond the "air space" is or is not part of the territory of the state below.

Before considering the space beyond the air space, it might be noted that the air space itself has not been precisely defined. Does it extend to the upper atmospheric regions; and if so, are its limits to be defined in terms of the composition of the gases or the density? The most reasonable rule would seem to be one that defines the air space in terms of the atmospheric elements necessary to "lift" aircraft; a limit expressed in these terms would be in keeping with the purpose and intent of the treaties relating to aviation, which have thus far defined the upper limits of state sovereignty.

When we go beyond the air space we are legally in a no-man's world. Theories have, however, been suggested to extend state sovereignty above and beyond air space. One view suggested by a distinguished authority is that the "territory of each state should extend upward into space as far as the then scientific progress of any state permits such state to control space above." (John C. Cooper, *International Law Quarterly*, July, 1951, p. 418.) It is difficult, however, to envisage how this principle of effective control can be applied in the regions above the air space. Perhaps it means the space in which a national state can control (i.e. prevent) the passage of a rocket spaceship.

* *A paper read at the Hayden Planetarium Symposium on Space Travel.*

But would not that mean that whenever any state could interfere with the movement of a spaceship, it would be considered to have the right to do so. Is this not in effect a rule that might makes right? Would it not place space ships at the mercy of those national states which are able to interfere with their free passage? There does not appear to be any compelling reason in law or practice to carry state sovereignty this far. It is sufficient to limit the outer boundary of a state's territory as presently under international law, to the region known as the air space and not beyond.

Freedom of Outer Space—A Proposed Principle

If we exclude state sovereignty in the outer space what rules will apply? This does not seem to be an insuperable problem. We have an apt analogy in existing international law, viz., the regime of the high seas. The outer space, like the open sea, is not and should not be under the sovereignty of any national state whatever; in other words, no state can have the right to acquire this space any more than it has the right to acquire parts of the open sea. Nor similarly, should any state have the right to exercise jurisdiction or police parts of the outer space.

However, this does not mean that the outer space would be in a condition of lawlessness and anarchy. Like the high seas it would be governed by rules of international law which would provide for a degree of legal order and at the same time preserve the fundamental principle of its freedom.

Furthermore, the analogy of the high sea can usefully be extended to the spaceships. Each spaceship (including satellite ships), like a vessel, would have a nationality and all such ships would be subject to the applicable laws of the state of nationality. The details of legal control over persons and goods on board the spaceships would be governed by generally accepted rules of international law and by specific national laws that might be applied by the national state under whose flag the spaceship travels. In short, a national state would exercise jurisdiction not over the outer space as such, but only over the ships, the persons and the goods which are subject to the jurisdiction of that state. Presumably, many of the rules regarding the nationality of ships, the relations between the master, the crew, and the passengers, the punishment for crimes and similar legal questions would be taken from the present rules applying to vessels on the high seas.

There may, however, be one important exception to this analogy. The high seas, as is well known, may become a theatre of war and generally speaking, there is no legal prohibition against belligerent vessels utilizing and operating from the open seas; however, there can be a great deal of question as to whether the outer space should be allowed to become a theatre of war or the base of military operations. I am not in a position to discuss the damage that may be caused by a satellite ship in outer space devoted to military purposes but there can be no doubt that its potential danger would far exceed that of a ship of war on the high seas. It may, therefore, be expected that there will be a demand that the use of the outer space for military purposes be outlawed. Whether in this day of total warfare one can expect agreement on this point is difficult to say—perhaps the fear of retaliation is the only

safeguard. In any case, it does not seem to be too early for the governments to give consideration to this aspect of the problem.

Claims to Celestial Bodies

When we pass from the region of outer space to that of the Moon and other celestial bodies, the legal issues become more complicated. For here the obvious analogy in international law is to new territories, i.e. areas which have been newly discovered and which through occupation and effective control, have been acquired by national states. One may raise some question as to whether under present scientific conditions these rules can be applied; human settlement would appear to be most improbable* and it is even difficult to envisage how a state could make its authority effective on the Moon.

But even if scientific development would make effective control possible, one might raise the question as to whether the Moon and other bodies should be considered simply as *res nullius*, free for occupation, in the same way as the undiscovered parts of the antarctic continent. Perhaps in these days of intensified nationalism some governments will be inclined to take advantage of the analogy to *res nullius* and attempt to stake out national claims to bodies in the outer space. But no doubt the great majority of people will find it difficult to accept the idea that the heavens themselves are to be parcelled out among individual governments. In their view these bodies, like the outer space, should also remain free for use by all. Here too the elements of legal order might be developed on the analogy to the open seas and one might even envisage that the special rules required would be established under the aegis of the United Nations. A legal development of this kind would dramatically underline the common heritage of humanity and would serve, perhaps significantly, to strengthen the sense of international community which is so vital to the development of a peaceful and secure world order.

SOLAR SYSTEM NOTES—2

By P. A. Moore, F.R.A.S.

During the autumn of 1951 Jupiter dominated the night sky, Venus that of early morning; while elusive little Mercury showed up well for a fortnight in mid-September. Now Jupiter is fast vanishing into the evening twilight, and both Saturn and Mars are coming into view.

In addition, all three of the remotest members of the Sun's family—Uranus, Neptune and Pluto—are to be seen, though Pluto is of course extremely faint. Uranus can be found closely north of the 3½-magnitude star Delta Geminorum, not far from Castor and Pollux. Neptune was even easier to find at the beginning of the year, as it was in the same telescopic field as Mars; on January 3 the apparent distance between the two was only a quarter of a degree.

These last two planets, Uranus and Neptune, have recently been receiving a great deal of attention in America. They are remote, inhospitable worlds, modelled (according to Wildt's theory) on the same plan as are Jupiter and Saturn; a rocky core, surrounded by a deep layer of ice and then a vast, gaseous atmosphere, made up largely of methane (the gas known to miners as the

* We should say this is far from improbable, on a really long-term view.—Ed.

dreaded "firedamp"). Uranus, discovered by Sir William Herschel in 1781 and at first thought to be a comet, can be faintly seen without optical aid; in large telescopes it exhibits a greenish disk, crossed by inconspicuous belts fundamentally similar to those of Saturn. Irregularities in the motion of Uranus enabled two mathematicians, Le Verrier and Adams, to predict the position of another large planet, Neptune, duly picked up by Galle in 1846. Neptune is too faint to be seen without a telescope, and its surface details are very hard to make out.

Recent American observations have established that Uranus is slightly the larger of the two planets, though it is rather less massive and must therefore be less dense. Both are approximately 30,000 miles across, so that our Earth seems a veritable dwarf in comparison. The "day" on Neptune is about 15¾ hours; the length of the Uranian "day" is still rather uncertain, but may be about 10¾ hours. A more exact value can be expected shortly. Contrast these short "days" with the long, dreary "years" of these two planets, 84 and 165 times respectively as long as ours!

Another by-product of this attention has been the discovery of two new satellites or "moons." Up to now Uranus has been credited with four (Ariel, Umbriel, Titania and Oberon) and Neptune with one (Triton), but during the past year or so "Miranda" has been added to the Uranian system and "Nereid" to that of Neptune. None of the satellites of Uranus can retain any atmosphere, as all five are much smaller than our Moon; but Triton, the aptly-named major attendant of Neptune, is well over 3,000 miles across and may be as much as 3,600, so that it is considerably larger than the planet Mercury. As it never approaches us closer than 2,700 million miles it has not yet been possible to prove or disprove the existence of a gaseous envelope; investigations are, however being made at the present time, by Kuiper and others.

Nereid, the latest addition to the known satellites of our Solar System, has a most interesting orbit. Some figures just issued by Dr. Van Biesbroeck, who has been making a special study of the object, give its orbital eccentricity as 0·76, which seems more reminiscent of a cometary path than a planetary one. In the course of its 359-day journey round Neptune, Nereid swings from 830,000 to more than six million miles from its parent planet. As it cannot possibly be more than 300 miles across, Nereid is certainly incapable of retaining any sort of air cover, and must be one of the most desolate spots in the Sun's system. Can it be that our remote descendants will use this lonely, icy little world as a refuelling base? We can only wait and see!

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The Moon at Last Quarter.

The eastern half of the Moon is shown. Ptolemæus appears prominently on the terminator, Alphons adjoins it to the S. (above), Albategnius to the W. The Apennines run from the terminator S.E. up to Eratosthenes; N. (below) of here Plato can be seen, showing up well on account of its very dark floor. The ray-craters Copernicus and Kepler appear to the E. of Eratosthenes, Aristarchus to the N. of Kepler, while the giant enclosure Clavius is not far from the terminator and close to the top (southernmost part) of the picture.

WHAT WE KNOW ABOUT THE MOON

By Patrick A. Moore, F.R.A.S.

(A paper read to the British Interplanetary Society in London on December 1, 1951.)

ABSTRACT

The Moon, as our nearest neighbour in space, will necessarily be the first goal in interplanetary travel, but will prove an inhospitable world. Water is certainly absent, and the temperature range unpleasantly great. A very tenuous atmosphere may however persist; some evidence of it is seen from time to time in the mists that cover the floors and walls of craters, and meteor trails have been strongly suspected. Higher forms of life are almost definitely out of the question, but the curious radial bands in a dozen or more craters may perhaps be due to a very low form of vegetation; and there are several cases of probable alterations in the surface features over the past hundred and fifty years. The popular belief that the Moon is a dead, changeless world may have to be modified in view of recent investigations.

Introduction

I do not suppose that any previous lecturer to this Society has risen with greater feelings of trepidation than are mine at the moment. Less than a decade ago, in the years immediately preceding the Second World War, the British Interplanetary Society was generally regarded as something faintly funny—and to the average man conjured up the picture of a number of elderly, white-bearded eccentrics piecing together odd machines of the type now relegated to children's comic papers. Times have changed; and nowadays the Society is recognized as being made up essentially of experts in the various fields of rocketry, engineering and navigation—even if a learned gentleman of the Press did recently describe us as "a society of dreamers," following up this somewhat sweeping statement with the interesting disclosures that the velocity of escape is five miles a second, that Phœbe is the brightest of Saturn's satellites, and that there are definitely no green areas on Mars!

The aim of the B.I.S. is to investigate and promote research into methods of travelling away from our Earth and reaching other worlds. I say "other worlds," but in point of fact only one cosmic body is under serious consideration at present, and that is our faithful companion, the Moon. There is an excellent reason for this; namely, distance. The Moon is an average of 238,000 miles away, while Venus, the nearest of the major planets, never comes closer than 26 million miles, which is more than a hundred times as far, and Mars is even more remote with his minimum distance of 35 million miles. It is true that occasional asteroids or Minor Planets pass fairly near to us—Hermes, in 1938, brushed past at a mere 900,000 miles—but these tiny worlds are poor objectives for the first interplanetary rocket. Come what may, we are forced back to consideration of the Moon, with which we have already made radar contact, and to-night I want to tell you something about recent investigations into the conditions upon our satellite.

The Lunar Terrain

First of all, let us look at a photograph of the Moon (reproduced opposite). The phase at the time of the photograph was Last Quarter, which means that

half only of the Moon is visible; as our satellite shines by reflected sunlight, only the daytime hemisphere is luminous, and in this picture only half the daytime hemisphere is turned towards us. The visible part of the Moon's circular edge is known as the Limb, the jagged boundary between day and night hemispheres as the Terminator—an important distinction; the position of the terminator alters steadily, and a couple of hours will make quite a difference. Lunar formations are most conspicuous when near the terminator, as all shadows are then magnified. As in all astronomical work, the south is at the top of the picture and the north at the bottom—a universal convention, as the normal telescope presents an inverted image—and the scale can be judged from the information that the Moon's diameter is 2,158 miles. If you dropped our satellite into the Atlantic Ocean, she would just about fit.

A mere glance will show that the surface features are very different from those upon the Earth. Here, indeed, we see Nature in the raw! In place of our oceans, forests and prairies, we have vast dry plains, broken by innumerable formations of roughly circular form that we call the lunar "craters" and "walled plains." The darker areas are known as the "seas," and have been given romantic names, such as *Mare Imbrium*, the Sea of Showers, *Mare Nubium*, the Sea of Clouds, and *Oceanus Procellarum*, the Ocean of Storms; when first discovered they were thought to be true seas, but for centuries now we have realized that there is no water in them. Showers, clouds and storms are unknown upon the Moon. Yet there is probably an element of truth in the inference; in the far-off days when there was great volcanic acitivity on the lunar surface, Mare Imbrium and the rest may well have been seas of molten lava, now solidified into the great arid plains we see.

There are lofty mountains on the Moon. Perhaps the grandest of all lunar ranges, the Apennines, can be well seen on the photograph, running from the crater Eratosthenes north-westwards towards the terminator, and forming the south-western boundary of the Mare Imbrium; the range is almost 200 miles long, and contains summits rising to the neighbourhood of 20,000 feet. Truly, our Mont Blanc would be dwarfed in such company, while Shropshire's much-vaunted Wrekin would sink to the status of a mere ant-hill. Even the bright isolated mountain Pico, clearly seen here against the dark Mare background, rises to 8,000 feet above the surrounding country; and the towering Leibnitz and Dörfel Mountains, unfortunately never well seen owing to their position near the edge of the disc, are certainly a full 30,000 feet in height, loftier even than our Mount Everest. These lunar mountains are far higher relatively than ours, as they rise from a globe only one-quarter the diameter of the Earth; and they form yet another proof—if one were needed—of great past activity upon the lunar surface.

Erosion, the action of air and water, is absent on the Moon, and consequently the mountains are far rougher and more jagged than terrestrial ones. The first lunar mountaineers will be confronted with some novel problems, though at least a fall will be less disastrous owing to the weaker force of gravitation! Oddly enough the comparatively low Riphæan Mountains, which do not show up well on this picture, do seem to show signs of erosion; but it is unreasonable to suppose that one small area alone has been subject to such an influence;

and there seems no doubt that the appearance is deceptive, and due to some other cause.

The walled formations, ranging in size from the colossal "Bailly," 170 miles in diameter, down to innumerable tiny pits a few dozen yards across, are the most important of all the lunar surface features. These are of various types, and each crater has its own characteristics.

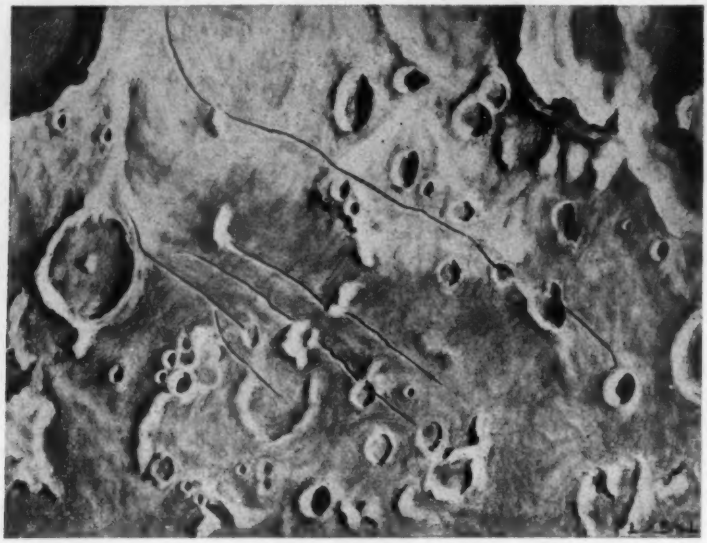
Let us look first at Ptolemæus, near the Moon's centre; the shape is pretty well circular and the diameter over 90 miles, so that if the English counties of Yorkshire and Lancashire were dropped into it there would be plenty of room to spare. The walls average 3,000 feet in height, with one peak rising to over 8,000. The floor is darkish, and contains one prominent craterlet about four miles across. Joining Ptolemæus to the south—that is, above on the picture—is another great formation, Alphons, and south again is a third, Arzachel, 56 miles in diameter, far deeper than Ptolemæus, and with walls rising over 10,000 feet above the depressed interior; on the floor is a large elevation or "central mountain." A glance will show that these central mountains are very common among the walled formations; look for instance at the smaller objects Bullialdus, Aristillus and Tycho.

Before passing on, mention must be made of the giant enclosure Clavius, nearly 130 miles across, and of the dark-floored lagoon-like Plato, about which I shall have more to say later; both these are approximately circular, but appear foreshortened into ellipses as they are comparatively close to the lunar limb. I should perhaps remind you that the Moon rotates upon her axis in the same time that she takes to revolve once round the Earth, so keeping one face permanently hidden from us—though because she travels in an ellipse, and moves quickest when closest to the Earth, we can often cheat by peeping a little way round her edge. I cannot resist quoting a piece of alleged verse composed by a housemaid in the service of a well-known poet, and somehow handed down to posterity:

> "O Moon, lovely Moon with the beautiful face,
> Careering throughout the bound'ries of space,
> Whenever I see you, I think in my mind—
> Shall I ever, O ever, behold thy behind?"

Next I must draw attention to the magnificent Copernicus, a large crater that appears to have scattered ash in all directions, giving rise to a famous system of Bright Rays. There are a good number of these ray-systems—Kepler's, too, is well shown here—but that of Copernicus is outstanding, rivalled only by that of Tycho. The latter system does not appear here, as it lies near the terminator, and the rays do not become visible until under a fairly high sun.

Lastly, let us look at the Straight Wall, so called because it is not straight and is certainly not a wall! It is in fact a fault in the surface; the ground to the east drops abruptly by 300 feet, so that an observer standing on the western plain would be confronted with an almost sheer cliff, while an observer to the east would look down over a terrifying precipice. This is by far the largest



East Gutenberg Clefts.

Drawn by L. F. Ball, F.R.A.S., December 19, 1948 1 hr. 10-in. Reflector. X260.

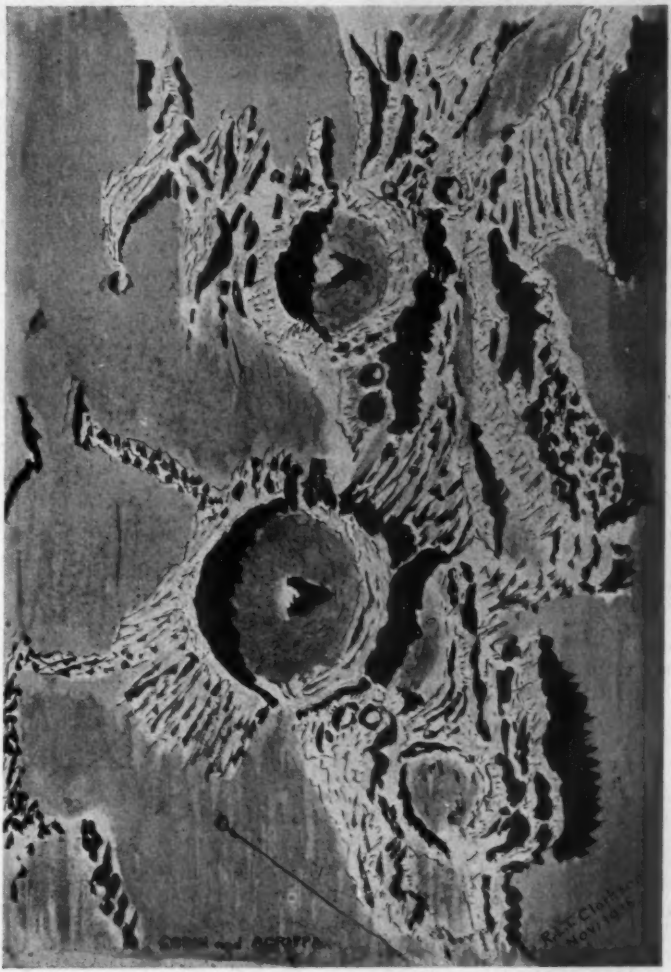
of the known faults on the Moon. In the future, when our satellite has become colonized, the Straight Wall will undoubtedly become a centre of tourist attraction! Also note the small crater Birt. It does not look impressive, but is actually of great interest, and will be referred to again later on.

Lunar photographs are frequently seen, even in the daily Press, and I prefer to illustrate the remainder of my lecture with drawings made by well-known contemporary observers—to whom I should like to express my thanks for making them available to me.

(*a*) *Clefts East of Gutenberg*

The first drawing is by L. F. Ball, F.R.A.S., and shows an interesting area near the crater Gutenberg.

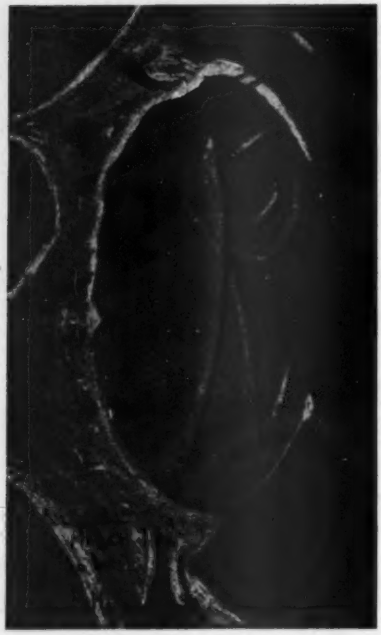
Gutenberg itself is a somewhat distorted walled plain over 40 miles in diameter, but of more interest are the clefts or rills seen to the east—gaping cracks in the Moon's surface, in this case over 100 miles long. These clefts are not uncommon objects. Perhaps they bear a superficial resemblance to river-beds, but there is almost certainly no real analogy; we have no evidence that the clefts are indeed old rivers, but plenty of indirect evidence that they are nothing of the kind.



Drawn by R. L. T. Clarkson, F.R.A.S., November, 1936. 6¼-in. Reflector.

(*b*) *Godin and Agrippa*

Both of the twin craters Godin and Agrippa are well-formed and strikingly alike in all respects and well illustrate the fact that craters often appear in pairs. I shall have more to say about this tendency later on.



Wargentin
Drawn by F. H. Thornton, F.R.A.S., March 1, 1950. 18-in. Reflector.

general impression of a flat cheese. of this type are few and far between; all the other examples are very small.

(*c*) *Demonax*

The formation known as Demonax is of very different type. It lies close to the Moon's southern limb, so that it appears very foreshortened. Demonax is over 80 miles in diameter, and the walls are of some height; but it is difficult to observe owing to its unfavourable position, and indeed had not been adequately charted even in rough until tackled between 1948 and 1950 by K. Abineri, D. W. G. Arthur and, to a minor extent, myself. To see Demonax properly we must wait until the Moon is suitably tilted relative to the Earth—or, more scientifically, until the "liberation" is favourable. The extent of the foreshortening can be gauged from the information that Demonax is really almost circular. There is no central mountain, though there are a couple of craters on the floor.

(*d*) *Wargentin*

Wargentin is an even more interesting object. Properly speaking it is not really a crater at all, but a plateau, as its interior has been filled with lava almost up to the brim, giving the Wargentin is not unique, but plateaux Wargentin itself is 56 miles across, but

Lunar Colours

One of the most noticeable characteristics of the lunar surface is that it lacks colour; the jet-black shadows contrast with the varying degrees of grey, but browns, greens, reds and yellows are absent, or virtually so. One or two areas are said to show definite colour; the Mare Crisium is reputedly greenish, as is the inside of the great crater Grimaldi, while Molesworth, Goodacre and Schmidt sometimes saw a bluish glare on the brilliant east wall of Aristarchus; Haas has recorded brownish hues in Hercules, Crüger, Stevinus and elsewhere. Mädler, between 1830 and 1837, frequently observed a reddish patch near the little crater Lichtenberg, which lies in a comparatively level area in the Ocean of Storms; more recently this has been seen by Barcroft (1940) and Baum (1948). But these hues are very fugitive. I have not personally seen any of them, and though it is true that my eye is not sensitive in this direction I

think there can be no question that colour, in the accepted sense of the word, is almost lacking in the lunar landscape.

Why should this be so? It seems that some material of uniform composition must overlay the entire surface. Dust is the obvious answer, and it is thus probable that the Moon is covered with a thin layer of ashy dust, not more than a few millimetres thick but quite sufficient to conceal any local surface colour. As to its nature, we can only speculate. It may be meteoric, but is more probably volcanic.

In this short time I cannot hope to give you more than the sketchiest and most incomplete of ideas of the nature of the Moon's surface. All I can do is to present a picture of a barren, rocky world, almost airless and quite waterless; unprotected from the blazing heat of the Sun or from the bitter cold of interplanetary night; a world where towering mountains rise from the silent plains, and giant craters mingle with ruined wall-plains and deep, gaping cracks. A dead world? That is the popular view; but I think that, as is so often the case, the popular view is too sweeping, and my main point to-night is to try to show you that our satellite is not quite so dead as used to be believed. To get ourselves fully in perspective, let us look back through the pages of scientific history and see what our illustrious predecessors had to say about the Moon.

Mapping the Moon

Modern selenography really begins upon that memorable evening in 1609 when Galileo first applied the telescope to the heavens. His imperfect "optick tube" was quite powerful enough to show the Maria or "Seas," the mountains and the walled formations well. From shadow observations, Galileo fixed the altitudes of some of the lunar mountains as 28,000 feet, which is certainly of the right order of magnitude—though it seems probable that the actual mountains observed were the Lunar Apennines and Caucasus, which are considerably less lofty. Between 1610 and the end of the following century various lunar maps were constructed, of varying degrees of accuracy; the best was Tobias Mayer's of 1775, but the first of the great selenographers was Johann Schröter, who observed at Lilienthal, near Bremen, between 1782 and 1813. Schröter spent many thousands of hours in studying and sketching the Moon's surface, and the importance of his work can hardly be over-estimated; his are the first reliable lunar drawings we have, and as they were made 150 years ago they are invaluable for checking purposes now. He was the first to see the long surface clefts, and to catalogue all his discoveries would take many pages of print. It is sad to relate that Schröter, most harmless of men, became a victim of the Napoleonic Wars; in 1813, when the French under Vandamme marched into Germany, the observatory at Lilienthal was burned to the ground, all Schröter's priceless notebooks destroyed, and the brass telescope and instruments plundered by the Frenchmen—who mistook them for gold! Schröter himself never recovered from the blow, and died two years later. The burning of the observatory was wanton destruction, but it is impossible to avoid drawing a parallel with the numerous European observatories and other centres of learning destroyed between 1939 and 1945. Human nature does not seem to have changed much through the ages.

Schröter believed that he had discovered extensive changes on the Moon's surface, and another observer, Gruithuisen, drew attention in 1822 to what he believed to be a true lunar city, constructed by intelligent Selenites. He described it as "a collection of dark gigantic ramparts, visible only on or near the terminator, extending about 23 miles either way." Gruithuisen was a well-known observer of his day, but in this case he had fairly let his imagination run away with him, and his "dark gigantic ramparts" turn out to be no more than low, haphazard ridges.

There can be no question of change here, as Schröter, a decade before Gruithuisen, and Mädler ten years later, both drew the region as it is to-day. Evidently it is best to treat such startling statements with rather more than a pinch of the proverbial salt.

The logical successor to Schröter was another German observer, Dr. Johann Mädler, who in conjunction with his friend Wilhelm Beer published a map and text in 1838. This work, "Der Mond," is a masterpiece of accurate and painstaking observation; for over half a century it remained the standard authority upon all lunar matters, and even to-day it is of great value. Oddly enough Mädler, who did nearly all the observing for the map, worked throughout with a refracting telescope of only $3\frac{3}{4}$ inches aperture, which is a significant answer to those misguided persons who believe that vast telescopes are necessary for useful astronomical work.

Strangely enough, "Der Mond" had unfortunate repercussions upon lunar study. Beer and Mädler stated uncompromisingly that the Moon was a dead, changeless world; the variations suspected by Schröter and Gruithuisen they attributed either to faulty drawing or fertile imagination. So far as Gruithuisen was concerned the charge was probably just; but even allowing for Schröter's rough draughtsmanship it is not safe to dispose of all his alleged variations in this way. However, the general view at the time was that Mädler's map was unlikely to be superseded; and if the Moon's surface remained eternally unaltered, there was really no point in observing it further.

Fortunately one skilful observer, Julius Schmidt, Director of the Athens Observatory, continued to take an active interest in the Moon, and in 1866 he made the announcement that a small crater called Linné, in the middle of the lava plain we call the Mare Serenitatis or Sea of Serenity, had disappeared, or at least changed its character completely. I shall return to this object later; for the moment it is sufficient to note that Schmidt's announcement had the effect of re-awakening interest in physical observation of our satellite. It would be both tedious and pointless to list all the various lunar works and maps that have appeared since 1866, and I shall confine myself to those directly concerning us to-night: Neison's book and map, published in 1876 (admittedly little more than a revision of Mädler's), Walter Goodacre's 77-inch map of 1910, and, last but by no means least, the great 300-inch map of H. P. Wilkins, present Director of the Lunar Section of the British Astronomical Association, and, I am glad to say, a Fellow of this Society. The great map was first issued in 1924, and is being constantly revised as fresh detail is discovered.

It might be thought that all hand-drawn lunar maps would by now have been superseded by photographs. Curiously enough this is far from being the

case; although invaluable in their way, the photographs will not show all the delicate detail that can be seen visually through a good telescope. The reason is not far to seek. The eye can wait for the rare moments of really good seeing, whereas the photographic plate is still collecting light during moments of atmospheric tremor, so that really fine detail becomes blurred. It is only very recently that the canals of Mars have been persuaded to imprint themselves upon a sensitive film, though they were first detected visually by Schiaparelli over 70 years ago. Some pictures taken at the Lick and Mount Wilson Observatories are splendid indeed, and I shall refer again to the photographic atlas of W. H. Pickering, the well-known American astronomer, issued in 1904; but all things considered, the eye, and not the camera, remains the essential equipment of the modern selenographer.

Terrestrial Effects

It is no part of my theme to-night to waste time in discussing the possible effects of the Moon upon terrestrial organisms. The name "lunatic" may or may not have a subtle significance—personally I hope it does not !—and there seems to be no definite proof that the Moon has any effect upon plant life. Kolisko of Stuttgart, who made extensive investigations between 1926 and 1935, was of the opinion that the phase of the Moon at the time of plant sowing had a strong influence both on the percentage of germination and the subsequent growth of the crop; but equally exhaustive studies by other workers do not confirm this, and there seems indeed no scientific basis for the idea. Nor is there any truth in the popular theory that the Moon affects the weather. On the other hand it is possible that our satellite has some influence upon radio. Atmospheric tides are as marked as those in the sea and land; as long ago as 1939 Appleton and Weekes showed the existence of a lunar tide effect in Region E of the ionosphere, and Howell claims that long-distance transmission conditions are most favourable on or around Full Moon. However, the subject has not been fully investigated as yet, and in any case the possible lunar influence is of no practical importance.

Origin and Crater Formation

Let us now spend two or three minutes discussing the origin of the Moon and of its surface formations. I do not propose to elaborate upon either of these subjects, as to do so would lead me well away from my main theme; in any case, we have to admit that we do not really know quite how the Moon came into being. It is most unlikely to be any older than the Earth; it may have been formed as a separate small planet, and attached itself to our gravitational pull early in its life-history. We do at least feel pretty sure that there was once a time, untold years ago, when the Moon was only ten or eleven thousand miles away from the Earth, and took only $6\frac{1}{2}$ hours to make one complete orbital circuit. Tidal friction drove the two bodies apart, until the present distance has reached 238,000 miles; and the Moon is still spiralling slowly outwards, and will eventually reach a distance of 340,000 miles. This will not be attained until the year A.D. fifty million, so that there seems to be no imminent hurry to complete our observations of the Moon before it recedes into the distance!

Even then the earth-moon system will not be stable; tidal friction will still be operative, and the two bodies will slowly come together again, until at last the powerful terrestrial pull will tear the Moon into pieces, scattering the fragments round and providing us with a ring like that of Saturn.

Nor are we sure how the lunar surface was moulded into its present shape, but it seems pretty safe to say that volcanic action is responsible. The lunar mountains seem to be analogous to terrestrial ones; and the various faults, ridges and clefts are easily explained in terms of ordinary geology. It is the craters and the so-called Seas, the Maria, which are the difficulty; and it is important to note that the well-defined seas are usually more or less circular, so that there may be no fundamental difference between a very large crater and a very small sea. There are, indeed, one or two objects which might be put into either category.

The main objection to the volcanic theory of crater formation is that lunar craters differ so greatly from terrestrial ones. On the Earth we have no volcanic crater of any real size; the greatest of the craters of Vesuvius would cut a very poor figure upon our satellite, and would certainly not be honoured with a separate name. Moreover the lunar formations present a totally different form, with lofty raised walls, depressed floors and often high central mountains, though no case is known where a central mountain surpasses the height of the outer rampart.

The wall height is absolutely very great, but relatively very small; in fact the lunar craters are not unlike flat dishes. To illustrate this we may take the example of Alphons, a vast formation near the Moon's centre with a diameter of some 70 miles. Although the walls rise 6,000 feet an observer standing near the centre would certainly have the impression of being on a flat plain, not in a hollow—and Alphons is a comparatively deep formation. An observer standing near the centre of the great walled plain Clavius, 130 miles in diameter (according to recent measurements by D. W. G. Arthur), would be unable to see the ramparts at all, though they rise to 10,000 feet—as they would be below the horizon. It must be remembered that as the Moon is much smaller than the Earth its surface curves far more sharply, and the horizon is correspondingly nearer.

In 1874, Nasmyth and Carpenter published a theory of crater formation that can well be described as the "fountain" theory; they postulated the existence of a central volcano, erupting violently and showering its débris in a ring around it. The theory is absolutely untenable—for one thing, the great walls of Clavius, for instance, contain much too much material to have been produced in this way—and R. A. Proctor revived an alternative theory of Gruithuisen's that the maria and craters were formed by large meteors, or lumps of rock, falling on to the Moon's still-plastic surface.

I do not know of any practical lunar observer who has any use for this theory to-day; but it is still often met with in general textbooks, and in the Festival Dome of Discovery was unfortunately presented as an established fact. As a matter of fact, it is as untenable as Nasmyth and Carpenter's volcanic fountain. We do know of a few meteor craters on the Earth; there is a famous one in Arizona, and the recently-discovered Chubb crater in Canada, between Hudson

Bay and Ungava Bay, is even larger, with a depth of 1,300 feet—but these objects are no more like lunar craters than are the cones of Vesuvius. Moreover the lunar craters are not distributed over the surface haphazardly, as would assuredly be the case were they due to chance impacts; I have already referred to twin pairs of the Godin-Agrippa type, and even more significant are the lines of similar craters known as "crater-chains." The examples of Vögel and the Hyginus Cleft will suffice.

The compound formation known as Vögel (not far from Alphons) is really made up of four craters joined together in a more or less straight line; are we to suppose that this arrangement was caused by the fall of a flock of meteors travelling together—a sort of family party? The celebrated Hyginus Cleft, near the lunar centre, looks at first sight like an ordinary crack in the surface, but is in fact made up of a large number of confluent craterlets. Hyginus itself—diameter 4 miles—is the larger formation in the centre. No meteors can have been responsible for these; it seems evident that crater-eruptions have taken place all along the line of weakness caused by the original surface crack.

There are numerous other arguments against the meteoric theory, but we need not go into these at present; nor need we waste time upon the glaciation theory, which supposes the Moon to be covered with a thick layer of ice. This latter idea is disposed of by the fact that the surface temperature has been measured, and rises during the daytime to that of boiling water. We are forced back to some form of vulcanism; and perhaps the most plausible theory is that when the lunar crust was beginning to harden above the still molten interior, huge domes were forced up around volcanic "feed pipes." These domes burst, with subsequent subsidence, the original "feed pipe" often piling up enough material to form a central mountain. The bright rays from Tycho, Copernicus and other craters are attributed to simple ash explosions, though why they are so long and so straight is still rather a mystery. This theory, due largely to the American geologist J. E. Spurr, has many unsatisfactory points; but on the whole it is the best that we can do at the moment, and it is enough to conclude that although the lunar craters may not be true "craters" in the sense in which we generally take the word, they are at least of igneous origin.

Admitting, then, great past volcanic activity, can we assume that this activity has totally ceased? I am not sure that we can; but before going into more detail it will be best to deal with the vexed question of an atmosphere, since the existence or non-existence of a gaseous envelope is obviously all-important when summing up just what kind of a world the Moon is.

Atmosphere

It seems reasonably likely that in its younger days the Moon had an appreciable atmosphere—volcanic activity is always accompanied by gaseous emission—but we have no justification in assuming that this atmosphere was similar in composition to ours. At any rate, most of any former atmosphere has now leaked away into space. The Moon is far less massive than the Earth, and the velocity of escape on its surface is less than 2 miles per second, as compared

with our 7. In other words, a particle projected upwards with a velocity of 2 miles per second will leave the Moon for ever; and all but the heaviest gas-molecules will long since have broken free from the feeble grip of our satellite. Theoretically, then, the Moon should be almost airless. From time to time she passes directly in front of a star, hiding or "occulting" it; the star does not flicker and waver before disappearing, as it would do were there an envelope of dense air surrounding the lunar limb, but snaps out instantaneously. The refraction effects of a lunar atmosphere would incidentally delay the time of occultation, producing a difference between theoretical and observed disappearance; but though the results of investigations are somewhat contradictory, no such discrepancy has been detected with certainty. The roughness of the lunar limb prevents the method from attaining the accuracy which might be expected of it.

We can thus be quite sure that the Moon's atmosphere is tenuous; but we are certainly not justified in saying that it is non-existent. In fact, what evidence we have is all the other way.

If there is an appreciable atmosphere, it should produce a lunar "twilight," which would be best observed near the "cusps" or horns of the crescent Moon. Schröter recorded this frequently, and regarded it as indisputable proof of a lunar atmosphere; Gruithuisen also observed it—but I am afraid that in view of his "lunar city" we cannot regard him as an unbiased witness! Even Mädler, the firm advocate of a changeless Moon, saw it; more recently it has been observed by the Rev. T. W. Webb, A. C. Ranyard, the Henry brothers at Paris and by W. S. Franks, among many others. A particularly fine twilight was seen by Franks on May 20, 1912, when the Moon was nearly four days old and the effect was very strong at both cusps. The main difficulty is that it is not easy to disentangle true lunar twilight from the well-known Earthshine. Earthshine is produced by the Earth shining upon the Moon, illuminating the dark side and producing the phenomenon known as "the Old Moon in the Young Moon's Arms"; it is often very powerful, masking any twilight effects, and we cannot therefore regard these observations as at all conclusive. True twilight, when observed, probably marks a local atmospheric condensation.

Better evidence is offered by occultations of planets. All the major planets are occasionally occulted by the Moon—though such phenomena are of course rare—and more than once Pickering and Douglass observed a dark band crossing the disk of Jupiter just before immersion, quite unmistakable and inclined at an angle to the Jovian belts, which they regarded as definite proof of a mantle of air covering the lunar surface; while Barnard made a similar observation in the case of Venus. Unfortunately Pickering's deduced value for the atmospheric density was 1/1800 of the Earth's, which is so much greater than the maximum theoretical value that it must cast doubt upon the accuracy of the whole method.

Schröter, Schmidt and others have seen grey borders to the jet-black shadows of some of the deeper craters, and similar observations have been made recently. I have myself seen a border to the shadow inside the crater Philolaus. There are several possible explanations; atmosphere might be responsible, even if it was confined to the lower parts of the crater concerned.

Fessenkoff, of Russia, attempted in 1943 to detect the polarization of a possible lunar twilight. He failed; but in 1949 Y. N. Lipski announced that he had successfully measured the atmospheric density in this way, arriving at a value of 1/10,000 that of ours. Like all reports coming from behind the Iron Curtain I think that this must be taken with reserve, especially as Lyot and Dollfus, working with the coronograph in the clear air of the Pic du Midi Observatory, do not confirm it. However, investigations there are still going on; and they have been successful in the case of Mercury, which is not much larger than the Moon, which gives reason for hope.

Now for the two most promising pieces of evidence in favour of air round the Moon; lunar meteoric phenomena, and surface mists.

Meteors strike the terrestrial atmosphere at the rate of thousands per hour. Nearly all burn away by friction against the air molecules, and comparatively few reach the Earth's surface as solid chunks. If the Moon is devoid of any atmosphere, its surface must be struck frequently; and in 1938 Dr. La Paz, of the University of New Mexico, calculated that there would be 100 annual impacts on the non-sunlit parts of the earth-turned hemisphere of an atmosphereless Moon bright enough to be visible to the naked eye from the Earth. Telescopically the number would be vastly increased. It need not be stressed that nothing like this is actually seen; flashes on the Moon are little more common than great auks on the Earth. The best modern instance is probably that of the flash observed in Plato by F. H. Thornton on October 19, 1945, at 11.24 G.M.T. While studying the interior of this great walled plain, which is 60 miles in diameter with comparatively low ramparts and a dark floor devoid of a central peak, he saw a minute but brilliant flash of light under the western wall—to quote his own description "it resembled the flash of an A.A. shell exploding in the air at a distance of about 10 miles. In colour it was on the orange side of yellow." But this is an isolated case—and moreover Thornton was using his 18-inch reflector, certainly the largest in Britain employed almost solely on lunar work. With my own 12½-inch, the flash might well have escaped notice.

Oddly enough, even a tenuous atmosphere would provide adequate protection against meteoric bombardment; the density lapse-rate would be much less than in the case of the Earth, and even if we assume a surface density of 1/10,000 that of ours, which is about the maximum possible, there would be a definite height at which the densities of the lunar and terrestrial atmospheres would be equal—above which the lunar would actually be the denser of the two! Even if we do not see the calculated number of flashes, therefore, it should be possible to detect meteor trails in the lunar atmosphere; and research upon this vital point has been, and is being, conducted by the Association of Lunar and Planetary Observers.

Results of these investigations have been reported in various articles in *Popular Astronomy*, in the *Strolling Astronomer*, the official organ of the A.L.P.O., and elsewhere, as well as in a hitherto unpublished article by Professor Haas which he was kind enough to lend me. Altogether, well over 20 objects have been observed which seem to be definite lunar meteors, and not mere terrestrial ones projected against the Moon's disk; they can be distinguished by their

faintness, their definite commencement and termination of path, and above all by their comparatively very slow movement. The final test will, of course, be the simultaneous observation of such an object by two observers very distant from each other. A terrestrial meteor projected against the Moon in, say, Glasgow would be well clear of the lunar disk from London; and if both stations recorded the object projected against the disk, it could not possibly be of terrestrial origin. This is the aim of present research; so far success has eluded us, but given reasonable luck the required proof should be forthcoming before very long. I do not think that there can however be any serious doubt that most of the objects referred to are genuine lunar meteors; and as it is impossible to have luminous meteors where there is no atmosphere, we are forced to the conclusion that the Moon is not the airless, dead globe that so many people imagine.

Unfortunately the spectroscope, that most powerful astronomical tool, is of no use to us here. The Moon, shining as it does by reflected sunlight, presents basically a much enfeebled solar spectrum; and it is beyond all possibility to sort out any possible lunar lines. It should be noted in passing that the spectroscope has so far failed to record water vapour lines in the spectrum of Mars, although since the Martian polar caps certainly consist of snow or ice we can be perfectly sure that some water vapour is present there.

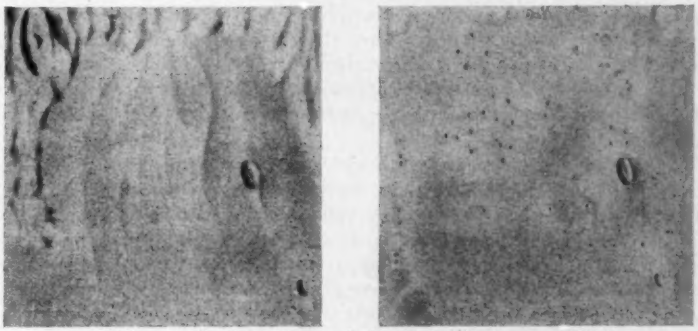
But if the Moon still retains a tenuous atmosphere, water is certainly lacking. The atmospheric surface pressure is very small, and the general conditions prevailing quite rule out the possibility of any liquid masses. I need not stress this; it is self-evident.

We now come to lunar mists. The existence of these cannot be questioned, as the evidence is overwhelming; various craters have at various times been seen mist-filled. For instance, on August 2, 1939, I saw the boundary and floor of the great walled plain Schickard completely covered with white mist; seeing was excellent, and all adjacent detail perfectly sharp and well-defined. By the following night traces of this mist were still visible, after which bad weather prevented any more observing. I mention this as a personal observation, but it is typical of many more made by selenographers of far greater experience and ability. Between 1865 and 1876 Neison often saw mist filling the interior of Plato, the formation mentioned earlier as the site of Thornton's flash; and the numerous tiny craterlets on the iron-grey floor of this interesting formation exhibit baffling changes of visibility, as though periodically obscured by vapour, though it would be premature to claim that this explanation has been definitely established. On January 21, 1951, R. M. Baum observed a very distinct cloud in the Humboldt Mountains, not far from the lunar limb, which lasted for three hours, and showed marked changes of form in that time. It was most unlucky that sudden clouds brought his observations to an end for the night. On February 10, 1949, Thornton saw a patch of vapour in the Aristarchus Cleft area, with all nearby detail beautifully sharp and well-defined. The interior of the crater Conon has likewise appeared misty to many observers of the present century, and—if I may be excused for producing another personal observation—a very fine example was seen by myself on August 20, 1951, in the crater known as Messier A.

I should like to dwell for a moment upon the two craters Messier and Messier A. Messier is about 6 miles in diameter, while "A" is rather larger; the former is oval, the latter approaches the triangular in shape. The cloud was much too prominent to avoid notice—it was in fact the brightest point for miles around, and as I have examined the area certainly not less than 500 times, under all possible lighting conditions, I think I am safe in saying that it was definitely abnormal.

The two ash-rays which extend eastwards from "A" give the object a queer resemblance to a comet, and are unique upon the Moon. In most cases a ray-crater has scattered its ash-lines in all directions, but it seems likely that the ash from Messier fell on to a surface that had not hardened sufficiently to retain it in its original straight lines—except in the one direction, where the two rays remain visible.

There is another interesting point connected with this area. Beer and Mädler, authors of the great work *Der Mond* of the last century, observed Messier and Messier A over 100 times between 1830 and 1838, and described them as exactly alike—perfect twins in size and shape. Yet nowadays they are palpably unalike. What is the explanation of this? At first sight a radical change would seem to be indicated, and may perhaps have taken place, but these two craters show strange alterations in appearance under different illuminations, and it would be hasty to jump to any conclusions.



1837. Southern Floor of the M. Crisium. 1950.

Drawn by R. M. Baum, F.R.A.S. The 1950 picture shows that the area is now speckled with craterlets and white spots, all of which are absent from the 1837 reconstruction based on Mädler's description.

Before leaving the subject of mists on the Moon, mention must be made of the variable area in one of the smaller and better-defined lunar seas, the Mare Crisium or Sea of Crises.

The southern part of this comparatively flat plain was drawn featureless by all the older observers and up to the beginning of this century; Goodacre's 1910 Map shows three tiny craterlets there. To-day there are at least 30 white spots and 4 or 5 distinct craterlets within range of a 3-inch refractor; using an 8½-inch reflector I have published a chart showing the positions of

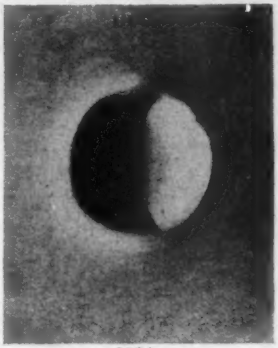
67—and Goodacre was using a 10-inch refractor of excellent performance! Four of these craterlets are joined by low ridges, giving the appearance of the so-called Quadrangle, first seen in its entirety by R. Barker a decade ago. It seems impossible that the excellent workers of the last century could have missed the Quadrangle, at least; and some change must have taken place. It is of course possible that the craterlets are of recent formation, but more likely that they were for many years shrouded in low-lying fog. Support for this theory is given by the fact that definite mists have been seen nearby. The prominent craterlet Graham, which lies to the north, was seen mist-covered several times by Birt, Neison and others; and extensive clouds have recently been seen in the whole area, quite covering the Quadrangle and all the other details.

Changes on the Moon

Let us now return to the subject of volcanic activity. We have seen that the lunar surface was once the scene of tremendous igneous upheavals. Have these upheavals ceased? It is difficult to say with certainty, though there is no doubt that any modern activity is on an infinitesimal scale compared with that of the remote past. In 1787 Sir William Hereschel reported three active volcanos on the dark hemisphere of the Moon; but we know now that what he saw were merely three normal bright points illuminated by earthshine. The crater Aristarchus, about which more anon, has a very brilliant central peak, and when the Moon is a thin growing crescent this peak can often be seen on the earthlit part glowing almost like a star. No; major eruptions upon our satellite can no longer occur. On the other hand one of the very last manifestations of expiring volcanic activity is the emission of carbon dioxide gas, and it does seem reasonable enough to suppose that this gas forms the mists seen from time to time in the bottoms of deep craters, though there of course no actual proof.

We know of no certain case of a lunar crater that has been recently formed. The floor of the small walled plain Halley contains a conspicuous craterlet well shown on an early lunar photograph taken by Rutherfurd in 1865, but strangely omitted by all previous observers, and there are other similar cases; but we must be very wary of jumping to conclusions, as the varying angle of illumination can alter a lunar landscape almost beyond all recognition in a very short time. On the other hand there are two cases of craters which seem to have disappeared, and which certainly merit a short discussion.

The first of these lies—or used to lie—near the border of Mare Crisium. The Sea of Crises again—how aptly named is this innocent-looking plain! Schröter drew the missing crater 150 years ago, and even used it as a point of reference; it was also shown by Mayer and other early workers. By Mädler's time it had vanished, and has not been seen since. Schröter may have been a clumsy draughtsman, but he never drew anything he did not see, and it is difficult to believe him guilty of so gross a mistake. H. P. Wilkins considers that change here is established, and that the crater may still exist, with a floor so lightened in hue that the formation is no longer recognizable. In such a case it seems to me that it would be hopelessly betrayed by its wall-shadow; but the mystery remains unexplained.



1834. Linné. 1951.

Drawn by R. M. Baum, F.R.A.S. The 1834 picture is a reconstruction of Linné as it seems to have been in Mädler's time; the 1951 picture shows the modern appearance.

An even more famous case is that of Linné, which was largely responsible for the revival of interest in the Moon in the latter half of the last century. Linné lies in the midst of the great plain known as the Mare Serenitatis, or Sea of Serenity; it is well-placed for observation, as it is not a great distance from the centre of the disk, and was described by all the older observers, including Mädler and Schmidt, as a deep, conspicuous craterlet very distinct even under oblique lighting—the diameter according to Schmidt being seven miles, and the depth a full 1,000 feet. Schmidt drew it thus in 1843; but in 1866 he startled the astronomical world by his bald announcement that Linné had disappeared, only a comparatively insignificant white spot remaining to mark the site. Certainly the modern Linné can by no stretch of imagination be described as a deep crater; all that remains is a tiny crater-cone, difficult to see even in large telescopes, surrounded by a curious white nimbus.

It seems almost impossible to avoid the conclusion that a radical change has taken place here, despite a rough and inconclusive drawing by Schröter in 1807 that is often cited as evidence against it. Mädler is hardly likely to have drawn and described a conspicuous crater where nothing except a white spot existed; remember, Linné lies on one of the levellest areas of the whole Moon, and there is no surrounding detail to confuse the issue. But the vital evidence is that of Schmidt, who observed the formation both before and after its metamorphosis and had no hesitation in stating that alteration had occurred. The obvious answer seems to be that some ground-tremor caused the walls of the crater to cave in, leaving a small hollow instead of a large one and powdering the nearby surface; and indeed it is difficult to see what else could have happened.

It is important to note that W. H. Pickering, famous American observer of the present century, was of the opinion that Linné's bright nimbus is due to hoarfrost; in support of this he claimed that its whiteness increased in size and brilliancy during an eclipse of the Moon, when the sunlight is suddenly

cut off from the lunar surface and the temperature there drops violently. (Pettit and Nicholson found that the temperature dropped from + 100° to −110° C. during the 1939 eclipse, indicating that the ashy surface is almost incapable of retaining heat.) Molesworth, in 1896 once saw that the bright spot had a phosphorescent appearance; and there are one or two other similar observations. Recent investigations have been inconclusive, and during the next few lunar eclipses there is to be a really determined effort to find out definitely whether or not Linné does brighten and enlarge in the sudden, bitter cold. A spot near Picard, in the Sea of Crises, seems to be made up of a similar kind of material, and it also has been seen blurred and strangely bright at times. During a recent lunar eclipse I thought it increased somewhat in visibility, but conditions, although fairly good, were not good enough for me to be sure.

While upon the subject of lunar temperatures, an interesting modern development should be mentioned. This is the measurement of temperature by the use of radio waves. Piddington, Minnett and others have been experimenting on these lines, and have obtained results for the lunar layer below the dusty outer cover—which latter is, of course, pretty well transparent to radio waves. The average temperature in the rocks just below the surface, at the lunar equator, is found to be about −24° C. with a variation of 50° C. in either direction. The difference between this result and that obtained for the actual surface, where the temperature range is so tremendous, is another proof of the very poor heat conductivity of the Moon's surface ash.

I have dwelt at some length upon these lunar mists and changes, as I think they are of particular interest to our Society, proving as they do that the Moon is not entirely a dead globe; and I have yet to touch on the celebrated crater bands, which may well indicate actual vegetal growth. Before doing so, however, it will be worth while to spend a short time discussing old ideas of life on the Moon, in order to lead up to modern opinions on the subject.

Possibility of Life

The idea that the Moon might be inhabited is a very old one; indeed, once it was realized that our satellite is a globe of planetary dimensions, it was tacitly assumed to be the abode of human beings. Many stories have been told of voyages there, and of strange and wondrous people living among its mountains and craters. But stories like this were written long before the B.I.S. could have been anything more than a fantastic dream; and if anything they sounded even more plausible 150 years ago than they do to-day. Witness the great Moon Hoax of 1835, which is certainly worth remembering.

Shortly before this time, Sir John Herschel, son of the even more famous discoverer of Uranus, had gone to the Cape of Good Hope, in South Africa, to make observations of the southern stars. Up to then the south polar regions of the sky had hardly been observed at all, as all the world's largest telescopes were in the northern hemisphere; Herschel had taken his own instrument with him, and was breaking almost new ground. As a matter of fact he did not mean to pay particular attention to the Moon and planets, which could of course be seen just as well from north of the equator; but a

graceless reporter of the *New York Sun*, an American paper with a pretty large circulation, had a bright idea. Herschel was on the other side of the world; communications in those days were slow and uncertain; who was there to check any statements he might care to make? Locke, the reporter, saw his chance, and took it. One day the *Sun* came out with a startling story. Starting with an involved description of Herschel's new telescope, which would have done credit to "Beachcomber's" famous Dr. Strabismus of Utrecht, it announced that various weird and wonderful forms of life had been discovered on the Moon, and that further details would follow. They did. Bees with giant stings, men with batlike wings, cows with six legs and green horns were all trotted out; and the world swallowed the story—hook, line and sinker! Article followed article; the story ran for a week (at the end of which time the *Sun's* circulation had been more than trebled), and for several months not only the public, but also many of the world's learned societies were utterly fooled. As soon as Herschel heard of the affair he naturally issued a denial, but this again was slow to circulate, and the *Sun* printed a suitably amended version of it just to confuse the issue further. All of which goes to show that little over a century ago most people were quite ready to believe in lunar life. Taken all in all, Locke's effort was easily the best hoax ever played on astronomers—it even beats the famous instrument supposed to have been invented by Professor Barnard in 1891, which was set up and calmly set to work discovering comets all by itself, ringing a bell when it had found one! (This particular hoax turned out to be the work of Barnard's Observatory colleagues.)

Nowadays we are a little more realistic (even if the American nation did suffer from mass-panic of invading Martians after a misleading broadcast of the famous Wells story in 1938), and we know for certain that any intelligent life of the kind we know is out of the question on the Moon. I say "of the kind we know," as I think this is an important qualification. A friend of mine once said that he was prepared to believe that there were intelligent beings on Mars that looked like cabbages and squeaked like mice. He did not think it likely—but it was *possible*. Still, once we start to consider totally alien forms of life the possibilities are endless, and speculation pointless; so we must necessarily confine ourselves to thinking about life *as we know it*.

It may surprise many people to learn that the last serious advocate of animal life on the Moon was not Wells, Verne or any other story-teller, but a very serious scientist—Professor W. H. Pickering, compiler of the photographic map—who in a paper published in 1924 suggested that certain dark patches near the crater Eratosthenes, a noble formation marking the eastern termination of the Apennines, were caused by swarms of insects. His main reason for thinking so was that the patches appear to shift very slowly about during the course of a lunar day. Pickering's paper indeed contains the following remarkable paragraph: "While this suggestion of a round of lunar life may seem a little fanciful, and the evidence on which it is founded frail, yet it is based strictly on the analogy of the migration of the fur-bearing seals of the Pribiloff Islands . . . The (lunar) distance involved is about 20 miles, and is completed in 12 days. This involves an average speed of six feet a minute, which, we have seen, implies small animals."

I do not think there is anyone now who upholds this strange idea; quite apart from more obvious difficulties, the shift in position of the Eratosthenes dark areas (which is well-established) is exactly the same at each lunation. This would make the hypothetical lunar insects or animals even more regular in their habits than is the average Englishman!

We must then admit that the moon-men of H. G. Wells and countless lesser authors must be relegated to the world of fiction; we know of no intelligent organism capable of managing without water and with virtually no air, and withstanding temperatures over 100 degrees on either side of zero. On the other hand it is within the bounds of possibility that low forms of vegetation may survive even under these rather uncomfortable conditions, and the search for such vegetation forms one of the most interesting branches of modern selenographical research.

I have already mentioned the interesting crater Aristarchus as being the brightest spot on the Moon, and the object that Herschel mistook for an active volcano. Photographs taken in ultra-violet light by Wood, Wright and others seem to indicate an unusual surface coating round about here, possibly sulphury in character and unique upon the Moon, but the form of Aristarchus is quite normal—a crater 23 miles in diameter and 6,000 feet deep, with a central peak (actually the brightest point of all) 2,000 feet high.

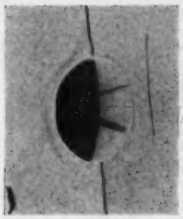
Aristarchus is about three-quarters of the way from the Moon's centre to the limb, and is thus elongated into an apparent ellipse. It has some dark streaks radiating from the centre, the so-called Radial Bands, that are to engage our attention now.

These bands seem to have been first drawn by Lord Rosse in 1863, and were again seen by Phillips in 1868, but not at all definitely; Schmidt made a large drawing of Aristarchus in 1866, but did not insert them or make any mention of them. Certainly they were not recorded by Mädler, Schröter or any of the earlier observers, who often recorded detail now much more difficult. Neison, in his great book of 1876, likewise ignored them; and so did Elger, whose small map published with his book in 1895 is still one of the clearest ever issued. Since then, the bands seem to have increased steadily in visibility, and to have grown in number from two to at least ten! The whole matter has been thoroughly investigated by Barker, and steady development seems to be unquestionable. Is it likely that detail now so easily visible would have been overlooked by Schröter, Mädler, Neison, Schmidt and the rest? I do not think so.

The bands have a definite structure, and the main ones extend over the wall on to the adjacent plain. Moreover, they seem to develop as the Sun rises over them. In the early lunar morning they are invisible, and as time passes creep gradually along, becoming broader and broader, longer and longer—reaching their maximum development just after lunar noon, and then fading away again. Recent studies of their periodical development by Matthew, Smith and Favarger bring this out clearly.

For many years Aristarchus remained the only object known to show these strange radial bands, but concentrated observation during the past decade has been extremely fruitful—more than a dozen systems are now known, though that of Aristarchus remains by far the most important.

BIRT. 1949 Jne. 5, 21h. 8. 6" O.G. x 325.



MOORE. 1949 Jne. 6, 21h 1. 6" O.G. x 325.

KIES A. 1951 Apr. 16, 23h. 4. 8½" Refl. x 330.

Craters with Radial Bands.

Look, for instance, at the little crater Birt, which is near the Straight Wall and which is associated with an important cleft; at the crater with which my own name (I feel undeservedly) has been associated, which is also connected with a cleft system: and at Kies A, not far off. All these show distinct markings of the Aristarchan type. The bands in Birt have been known since 1930; those in Moore were first seen by me in 1948, quite by chance, when I was examining the cleft system with a 6-inch refractor; and those in Kies A by K. W. Abineri, also in 1948. The Kies A band may be increasing in distinctness, as it is now as prominent as the main band in Moore—which was not the case three years ago. It is premature to claim that the radial band systems are of recent development, but it is odd—to say the least of it—that they remained undetected for so long.

What are these bands? I think they can only be vegetation. It seems to me likely that the original "band" is due to a crack in the lunar surface; when the Sun rises over it and warms it, a certain amount of gas is exuded, and the very primitive lunar vegetation can develop, to wither away again when enveloped once more in the bitter cold of a lunar night. The choice of composition for the gas is limited; it must be heavy, and there must not be much of it. Carbon dioxide seems a possible answer. Obviously we can only speculate about the exact nature of the vegetation itself. Personally I am quite ready to make botanical speculations—since I probably know less about botany than anyone else in this hall—and the vegetation may consist mainly of naked colloids. There seems no reason why this very low form of vegetal life could not flourish in the cracks on the Moon.

Vegetation has also been suspected on the floors of some of the larger craters, such as Aristillus and Endymion, where strange variations occur suggesting the presence of some growth, and may also account for Pickering's "insect swarms" of Eratosthenes; but I think I have said enough to prove to you that some people, at least, do not believe the Moon to be the dead, changeless world described in so many textbooks. The Queen of Night still holds many unsolved mysteries for us, and there is a never-ending pleasure in studying her tantalizing, sphinxlike face, tracking down the minute variations and sorting out those which are due to differences in lighting from those which are intrinsic.

The Other Side of the Moon

It may surprise some people to know that there has even been a little progress in investigating the hidden side of the Moon—that three-sevenths of the surface which we can never see. Earlier on we saw that some craters, such as Copernicus and Tycho, are the centres of great radiating lines of ash. In a few places, very faintly, rays can be tracked coming over the limb from the hidden side; and by plotting them and tracing them back, it is possible to form a good idea of the site of the crater responsible for them, though we can never see the crater itself. Pioneer work here has been done by E. F. Emley.

A recent chart by Wilkins, based on observations by Emley, himself and myself, indicates a number of such averted ray-centres, and efforts to hunt down others are still going on.

People often ask me why I spend hours gazing at the Moon through a telescope. "What's the use?" they ask. Well, one day it will be possible to go there; and it is only common-sense to find out as much about it as we can. If I want to visit a foreign country, I do not merely pack a suitcase and jump on board the first aeroplane; if I have never been there before, and know nothing about it, I buy a travellers' guide. What we are trying to do at the moment is to form a travellers' guidebook for the Moon; and even if we ourselves are never able to use it—well, in the years to come other people will.

NOTES AND NEWS

Swiss Astronautical Association

We have recently received news from Ing. J. Stemmer of the formation of the *Schweizerische Astronautische Arbeitsgemeinschaft* at the end of September, 1951.

This young society has Ing. Stemmer as its Technical Director and Ing. E. Klöti as Secretary, and hopes to issue a Technical Bulletin in due course.

Journal of the American Rocket Society

The *Journal of the American Rocket Society* has lately acquired a new and impressive format, and is henceforth to be issued (like the *B.I.S. Journal*) at bi-monthly intervals, instead of quarterly. The first of this new and enlarged series was the September issue (Volume 21, No. 5), and consisted of 48 pages, size 11¼ in. × 8½ in. Edited by Dr. Martin Summerfield, the contents were:—

Optimum Thrust Programming for a Sounding Rocket—Tsien and Evans.
A Theory of Unstable Combustion in Liquid Propellant Rocket Systems—Summerfield.
Single Flow Jet Engines—Foa.
Approximate Calculations of Specific Heats for Polyatomic Gases—Meghreblian.
The Hypergolic Reaction of Dicyclopentadiene with W.F.N.A.—Trent and Zucrow.

The B.I.S. extends a hearty welcome to this new publication from our friends in the A.R.S., and hopes that it may long continue as a valuable addition to the periodical technical literature of rocketry.

The *A.R.S. Journal*, of course, is not strictly comparable to our own; whereas we have always concentrated (and shall continue to do so) on the interplanetary aspect, it is primarily concerned with the chemistry and engineering of rocket power plants and projectiles. This difference is well brought out by the respective names of the two societies. Also, the A.R.S. publications show an interest in what we, over here, call "jet propulsion" (i.e. air-burning turbojet and ramjet engines), which, for a rocket society, seems rather strange to British eyes.

However, we have reason to believe that the *A.R.S. Journal* will display an increasing future concern with specifically astronautical matters, and (as might be expected) we welcome this most of all.

Journal Bindings

A few Cordex Volume 10 binders are still available at 6s. 6d. (post free) for members who would like them.

These binders will not be available for the future, since we have been able to make greatly improved arrangements with our printers who have undertaken to bind *Journal* volumes permanently for an inclusive charge of 8s. (post free).

The volumes will be bound in dark green, suitably lettered in gilt on the spine, and title pages will be added by the binder.

Arrangements have also been made whereby previous volumes of the *Journal* may also be bound in similar manner, and enquiries about this should be sent direct to W. Heffer & Sons, Hills Road, Cambridge, *and not to the Society*.

Sixth Annual General Meeting

The Sixth Annual General Meeting of the Society was held at Caxton Hall on December 8, 1951, when the Chairman, Mr. A. C. Clarke, opened the proceedings by amplifying a number of points appearing in his printed address, which had been circulated to all members beforehand with the *Annual Report*.

Following this, the Secretary read the Auditor's Report and the Chairman then proposed that the audited Balance Sheet and Accounts for the year ended September 30, 1951, be approved. The motion was seconded by Mr. O. B. Howell and carried unanimously.

The Chairman then drew attention to the problem of finding office accommodation for the Society in the near future, and explained that this was receiving the attention of the Finance and General Purposes Committee at the present time. A number of lines of approach had already been investigated, and although no final decisions had been taken, it was already clear that rents in the Central London area were exceedingly high, and it might prove more advantageous for the Society to buy a house.

When drawing up the Society's original Constitution, specific safeguards had been included to prevent money being borrowed without good reason, but the Council now felt that the time had come when authorization should be

sought from the members to borrow money in order that the question of acquiring premises on mortgage could be gone into. If this particular suggestion was not proceeded with, the authorization would then automatically lapse.

With this in mind, the Chairman said he wished formally to propose a motion that the Council be empowered to borrow money up to a maximum of £5,000 for the purpose of establishing office accommodation for the administration and records of the Society and to throw the matter upon to discussion.

A short discussion followed, from which it was clear that all the members present endorsed the Council's view, and after Mr. P. R. Freshwater had seconded the motion, it was put to the vote and carried unanimously.

Following this, Mr. Freshwater rose again to say that in his view it was undesirable that the Council should always be cramped on this particular question, and he would like to propose the motion that the Council be given standing powers to borrow up to a maximum of £500 for general purposes, at their discretion.

This suggestion met with general approval, and after being seconded by Mr. A. E. Dixon, was also carried unanimously.

The Chairman then read the Report of the Scrutineers on the election of four new Members of the Council by postal ballot.

The Report gave the number of ballot papers received as 590, and the names of those elected were:—

J. Humphries	H. E. Ross
W. N. Neat	Dr. L. R. Shepherd

Mr. Clarke said he was very pleased to welcome the election of Mr. Neat, for he would not like it to be thought that election to the Council was quite automatic, and he hoped to see steady "blood transfusions" in the future as the older Members of the Council dropped out through sheer exhaustion!

Following the conclusion of the main business, a general discussion on the Society's affairs then followed, during which a number of interesting topics were broached, including a plea from Miss H. Winick that some record be made of the discussions following lectures.

The Secretary replied to this by saying that he would very much like to see summaries of these discussions in the *Journal*, but it was an unfortunate fact that at present we simply had not room. It was very much to be hoped, however, that we should be able to adopt this practice as the Society grew.

To conclude the meeting, Mr. E. Hope-Jones moved a vote of thanks to the Chairman, and observed that it was a function which was by no means as easy as it looked, This motion was seconded by Dr. J. A. Moyse and carried unanimously.

R.Ae.S. Award to Mr. A. V. Cleaver

The Royal Aeronautical Society this year awarded their Herbert Akroyd Stuart Memorial Prize to A. V. Cleaver, for his paper "Rockets and Assisted Take-off," read before them on November 23, 1950. The award was made on the occasion of the Wilbur Wright Memorial Lecture on September 10,

1951, and is given for the most valuable contribution received on applied thermodynamics.

Dr. Sänger and Fräulein Dr. Bredt

We are delighted to announce the marriage of Dr. Eugen Sänger and Fräulein Dr. Irene Bredt, which took place in France during October. Dr. Sänger, an Honorary Fellow of this Society, is of course famous as a pioneer of rocketry and was elected the first President of the International Astronautical Federation at the London Congress this year. Dr. Bredt has, for many years, been the collaborator of Dr. Sänger in many technical papers.

Additions to Lending Library

The following books have been added to the Society's lending library and are available to Fellows holding library tickets:—

Meteoric Dust, by J. D. Buddhue (1950).
Aviation Medicine in its Preventive Aspects, by J. F. Fulton (1948).
A Handbook of Space Flight, by Proell and Bowman (1950).
The Conquest of Space, by D. Lasser (1934).
Rakieta Ksiezycowa, by E. Bialoborski (1950).
Behind the Flying Saucers, by F. Scully (1950).
Die Erreichbarkeit der Himmelskörper, by Hohmann (1925).
Raketenfahrt, by Valier (1930).
The Moon, by T. G. Elger (1895).
The Moon, by R. A. Proctor (1873).
The Origin of the Earth, by W. M. Smart (1951).
The Telescope, by Bell (1922).
The Testing and Adjustment of Telescope Objectives, by H. Dennis Taylor (1946).
Space Medicine, Edited by J. P. Marbarger (1951).
Guided Missiles, Rockets and Torpedoes, by F. Ross, Jnr. (1951).
La Planete Mars, 1659–1929, by E. M. Antoniadi (1930).
The Exploration of Space, by A. C. Clarke (1951).
Making Your Own Telescope, by A. J. Thompson (1951).

From the World's Press

A good deal of publicity was recently caused by an article in the *Daily Mirror* about a "Space Passport" produced as a practical joke by one of our members, and a photograph of such a passport, purporting to belong to our Chairman, was produced.

We wish to make it quite clear that this document has no official connection whatsoever with the Society, and the copy shown did not belong to Mr. Clarke, who had no prior knowledge of the article and arranged for a disclaimer to appear in a subsequent issue.

* * * *

As described in the Annual Report, the Second International Astronautical Congress, held in London last September, provoked literally hundreds of press items in newspapers all over the world; the coverage extended throughout the United States, Europe and the British Commonwealth, and reached out

even into countries such as Iraq and Borneo. One might reasonably conclude that now there can be few literate persons anywhere on this planet who are ignorant of the modern interest in space-travel!

Nearly all of this press coverage of our aims and activities was sympathetic, reasonable, and well-informed, so that it should be made quite clear that some of the items on which comment is made below are far from being typical.

The *Daily Worker* of London wound up quite a good article on rocketry and spaceflight by explaining that "the vast majority of the work now being carried out by the United States and British Governments, in New Mexico and Australia, is directed toward the development of rockets that may be used against the U.S.S.R.," while "So far as we know, the Soviet Union is not spending much time or money on rocket research." As a counter-blast to this, one might cite the American *Washington Post*, which headlined an interview with Koelle of the G.f.W. "Reds Reported Working on Space Base."

One of the most interesting features of all this journalistic activity was the correspondence which followed it. Again, much of this was on quite an intelligent level—but some of the hardy annuals of the old era of scepticism and hostility made their reappearance.

There were, for example, still a number of people who did not believe rockets would work in a vacuum. "There's nothing to pull or push on," wrote "A.R." to the *Dundee Courier and Advertiser*, adding: "It is all a fascinating dream, but simply chimerical." A Mr. Thorburn, in the *Newcastle Journal* also complained that "If we ask if this statement (about rockets working *in vacuo*) has ever been proved correct, we get no reply," and concluded "The whole assumption is, I am afraid, a fallacy and should either be proved or discredited." There was a time, only a few years ago, when B.I.S. officials hastened to reply in print to such statements, but now we have no need to bother; many other people, unknown to us, rush in and give the true facts, delighted to air their knowledge.

The same applies to the objectors on moral grounds. A *Reynolds News* correspondent pointed out "the possibility that God is not at all likely to allow man, who has already made a mess of the Earth, to pollute another part of the universe." In rather similar vein, a Mrs. Sidebotham told the *Manchester Evening News* that "this reaching-the-Moon business . . . is interfering with God's Good Plan"; she was supported by one other writer, who went even further, saying "It is quite certain that such interference with God's works can only be the work of madmen or the Evil One and will bring disaster to the world." Mrs. Sidebotham was answered by Mr. Bracegirdle (*these names are quite genuine—Ed.*), who wrote: "Well, I haven't the foggiest idea what God's Good Plan is and strongly suspect that your correspondent doesn't know either. But I do know that much the same objections were raised when Columbus sailed west . . . When man finally explores the Solar System and begins reaching out across the interstellar void to the stars, I expect these people who know all about God's Good Plan will be raising the same objections." A Mr. Foster tentatively suggested that "Perhaps God's plan is for all worlds to unite. When this is achieved at least we on this planet won't be worried

about Persian oil, Iron Curtains, atom warfare, and perhaps other civilizations will be relieved from their worries, too." He added "Please do not publish my address just in case some crackpot on Mars doesn't agree with me."

The question of interplanetary relations interested many people: a Mr. Peter Wright of Monte Carlo wrote to the *Continental Daily Mail* "Surely an invasion by humans of another planet would not necessarily set off an interplanetary war, as suggested by Mrs. J. Lamothe (September 5) . . . it is much more feasible that before a flight to another planet, the whole world's attention would be on this adventure and would turn such items as Korea, Persia and World War III to back-page news. If, on the other hand, we were to believe that an interplanetary war were imminent, then . . . we would all unite as one to defend our own planet, which—who knows—may be the only answer for everlasting peace."

Rather less idealistic views were expressed to the *Portsmouth Evening News* by a Mr. O'Grady. Evidently a keen cinema-goer, he said: "The nation or power that first occupies the Moon will, no doubt, be in a position to dictate to the whole of this world and our hope must be that a western nation will be first." He believed "That man will conquer space is no longer a probability; it is a certainty, and as in the past Celtic and Latin men . . . were the imaginative thinkers . . . so the likelihood is that it will be men of these races who will be the first . . ." In a truly wonderful flight of Irish eloquence, he began his letter: "Ignorant, narrow and credulous minds have in all ages been terrified and over-awed by the unknown; the light of knowledge has always been hailed as black magic, and the glorious achievements of enlightened scientists and pioneers as the work of imaginary Satanic powers," and concluded: "As the timid, the fearful, the cringing, and the superstitious have always opposed progress, so it is only natural that history repeats itself, but new Galileos will arise and to-morrow's youth and the children of to-morrow's to-morrow will make the venture with faultless courage and faith, for nothing can shake the belief of youth in its ability."

Sure, and that's telling 'em, O'Grady!

* * * *

Much of the editorial comment on the Congress was concerned with the aims and objects of space-flight, the motives underlying any attempt to achieve it, rather than the technical means. Some of this discussion was facetious (e.g. ascribing a motive of pure escapism), but most of it was not; typical of the serious category was a reference in *Flight* which drew the following letter from Mr. A. V. Cleaver of our Council:—

"In your September 14 note on the recent London Congress on Astronautics you expressed the views that the achievement of space-flight would cost millions, that only governments could afford to sponsor such a project, and that "no government is likely to overload its exchequer without the compulsion of a military aim."

"With all of these opinions, as a true statement of the present situation, I am in complete agreement. I do not, for example, dissent in any way from the view that the main current expenditure of our Western governments must

be on defence. (If it is not, then the question of any subsequent expenditure on astronautics may remain purely academic for a long time to come; from the purely astronautical viewpoint, it is no more than a happy coincidence that such a programme still makes a large, if indirect, contribution towards our ultimate objective.)

"However, I should be grateful for a little of your space in which to register a protest against the facile belief that large expenditures on (for example) astronautics will *always* be unlikely "without the compulsion of a military aim."

"It is all a question of the standard of values accepted, at a given period, by mankind. In the past, earlier cultures have variously put their main effort into art, religious practices and architecture, preparations for a dubious after-life (as exemplified by the Pyramids), and so on. We of the twentieth century concentrate on the development, manufacture, and employment of technically advanced means for mutual destruction. . . .

"Is it too much to hope that one day we may be civilized? After all, exploration and the search for new knowledge and experience have always rated a high priority in man's activity. On this basis, the full mastery of his powers of flight, leading eventually and inevitably to flight beyond the atmosphere and to other worlds, is seen to be an end worthwhile in itself. The "compulsion" involved goes far deeper than any merely military or commercial consideration.

"Furthermore, while such an effort would undoubtedly be very costly, its expense would still be only a small fraction of that demanded by modern war, when measured in terms of either money or human life."

* * * *

The preceding reference to the motives for space-flight are not so irrelevant as all that to one of the fine series of "Profile" articles in *The Observer*, which appeared on November 25 and dealt with Mount Everest. Mallory's reply, to the question of why he wanted to climb Everest, was quoted: "Because it is there." The essay was concluded with some observations on mountain-climbing in general:—

"By any material standards it is an utterly useless enterprise; it is a supreme type of disinterested activity, an affirmation that men, of their own will, can rise far above their needs of food, comfort and safety. It is an enterprise that calls for the highest pitch of men's strength, courage, intelligence and imagination; and that can give nothing back to them but the satisfaction of having done it."

We believe that, in due course, other and more "practical" reasons for space-flight will become evident; nevertheless, those described in the *Observer* paragraph above will no doubt always continue to exert a powerful influence on the minds of many pioneer astronauts. We believe that most pioneers just are made that way.

* * * *

The *Daily Express* recently printed a picture of a British rocket in flight "larger than a V.2"; we hope none of our readers were deceived. As *Flight* pointed out on October 26, it was only a supersonic test vehicle 24 feet long, even including its tandem solid-propellant booster stage.

ABSTRACTS

Edited by J. HUMPHRIES

Abbreviations of titles of journals were given in the May, 1950, issue of the *Journal*, and addenda have appeared in subsequent issues.

Many of the articles noted are available on loan to members resident in the British Isles. Requests should be addressed to J. Humphries, 97, Churchill Avenue, Southcourt, Aylesbury, Bucks.

AERODYNAMICS

(1) **Guided missile friction heating.** R. MCLARREN. *Aero. Dig.*, **63**, 27-29, 80, 82, 84, 86 (*Aug.*, 1951).
Review of current theories.

AIRCRAFT

(2) **Evolution of the Jato motor.** ROGERS. Aerojet Lecture, No. 7, 19 pp.

(3) **Operating instructions for Model 14AS-1000 Jato motors.** Aerojet Rept., No. 440, 8 pp.

(4) **Rockets—their future in military aviation.** A. V. CLEAVER. *Aircraft*, **29**, 12-14, 42, 44 (*Jan.*, 1951).
Review of the present state of rocketry and possible future applications.

(5) **The rocket-powered intercepter.** *Flight*, **59**, 645-8 (*1st June*, 1951). Condensed version of "Application of rocket power to aircraft," H. R. MOLES, *Aero Engng. Rev.*, **10**, 24-30 (*April*, 1951). For abs. see *J.B.I.S.*, **10**, 222 (*Sept.*, 1951), abs. No. 125.

ASTRONAUTICS

(6) **The evasion of hazardous objects in space.** W. PROELL. *J. Space Flight* **3.** Pt. I (4), 1-6 (*April*, 1951). Discusses the conditions for missing hazardous objects. Pt. II (5), 1-9 (*May*, 1951). Discusses detection, sensory devices, evaluation of hazard, and the actual operation of avoiding contact.

(7) **Fundamental dynamics of reaction-powered space vehicles.** L. N. THOMPSON. *Inst. Mech. Engrs. Advance Paper*, 12 pp. (*May*, 1951). Also in *Aircraft Engng.*, **23**, 228-234 (*Aug.*, 1951).
The concept and importance of "escape velocity" is dealt with first, and then the elementary mass-ratio equations for the motion of a space vehicle under various conditions are derived. Available energy sources are considered next, the operational parameter being jet velocity. It is indicated that the maximum jet velocity conceivably attainable with chemical fuels is of the order of 20,000 ft./sec. Nuclear fuels are dealt with and it is shown that, while energy potentials are very high, the problem of practical utilisation is formidable. A thermodynamic type of atomic rocket motor employing an inert reaction mass to absorb the fission energy is postulated, and it is demonstrated that the heat transfer and materials requirements present a problem of the first magnitude. The influence of propellant density on the performance characteristics of both chemical and atomic rockets is discussed, and it is shown that propellants giving high jet velocities may not necessarily be the best to use. Orders of magnitude for the mass ratios required for various interplanetary flights are established, and it is indicated that only atomic drive will render them small enough to be attainable in practice. It is concluded that, unless nuclear energy can be suitably harnessed, economical space-travel will not be feasible.

(8) **The application of thermoelements in space.** L. GEILING. *Weltraumfahrt* (3), 59-60 (*June*, 1951) (*in German*).
Using elements composed of 90 per cent. bismuth + 10 per cent. antimony and 75 per cent. antimony + 25 per cent. cadmium it is possible to obtain 1 kw. power in the earth's orbit for a total weight of 150 kg. and surface area of 400 m^2.

(9) **The problem of the extraterrestrial sun mirror.** W. SCHAUB. *Weltraumfahrt* (3), 55-60 (*June*, 1951). (*In German.*)
In order to double the light intensity of a 5 km. diameter area on the day side a mirror at 1,000 km. altitude would need to be 10 km. diameter. It is concluded that such a project is impracticable.

(10) **From sea navigation to astronautics.** K. SCHÜTTE. *Kosmos*, **47**, 241-244 (*June*, 1951). (*In German.*)
Methods for obtaining a spaceship's position.

(11) **Interplanetary flight.** *Mechanics*, **60**, 367, 374 (*Aug.* 31, 1951).
Applications of rockets and elements of satellite vehicles.

(12) **Interplanetary bases—the Moon and the orbital space-station.** F. R. FEARS. *J. Space Flight*, **3** (7), 4-5 (*Sept.*, 1951).

(13) **Steps towards space travel.** A. E. SLATER. *Aeroplane*, **81**, 421-422 (*Sept.* 28, 1951).
Review of Second International Congress on Astronautics.

(14) **The earth-satellite vehicle.** *Flight*, **60**, 449 (*Oct.* 5, 1951).
Review of the Second International Congress on Astronautics.

(15) **Second International Congress on Astronautics.** J. HUMPHRIES. *Nature*, **168**, 733-734 (*Oct.* 27, 1951).
Review of several of the technical papers.

ATMOSPHERE

(16) **Discovering the secrets of the ionosphere.** J. GAUZIT. *Science et Vie* (404), 307-312 (*May*, 1951). (*In French.*)

(17) **The atmospheres of the planets.** G. HERZBERG. *J. Roy. Astr. Soc. Canad.*, **45**, 100-123 (*May-June*, 1951).
Reviews the present status of spectroscopic investigations of planetary atmospheres including that of the Earth (35 refs.)

(18) **Variations in the chemical composition of stratospheric air.** K. F. CHACKETT, F. A. PANETH, P. REASBECK and B. S. WIBORG. *Nature*, **168**, 358-360 (*Sept.* 1, 1951).

BIOLOGY AND MEDICINE

(19) **Radiation effects on man in space.** K. BUETTNER. *Bull. Amer. Met. Soc.*, **32**, 183-185 (*May*, 1951).
Considers the effects of cosmic ray heavy primaries, cosmic ray showers, solar radio microwaves, hard solar X-rays and the solar radiation claimed to have been discovered by Takawa. It is concluded that cosmic ray primaries are the most dangerous and may limit the safe time above 20 km. to the order of hours.

(20) **What is the probable behaviour of the human organism in space?** H. STRUGHOLD *et al. Weltraumfahrt* (4), 81-88 (*Aug.*, 1951). (*In German*).
A symposium of short papers by leading medical experts. With one exception all contributors consider that no-g. conditions will have no lasting effects. LANGER, however, considers that life may only be possible for minutes since the heart may not function correctly.

CHEMISTRY

(21) **The freezing-point diagram of the hydrazine-water system.** T. C. HILL and J. F. SUMMER. *J. Chem. Soc.*, 838-840 (*March*, 1951).

(22) **Ozone safely liquefied, has important uses, says A.R.F.** *Chem. Engng. News*, **29**, 2474-2475 (*June* 18, 1951).
Large scale production now a possibility. Use as a rocket oxidant stressed.

MATERIALS

(23) **High-temperature ceramic materials.** H. B. MICHELSON. *Prod. Engng.*, **22**, 120-123 (*Aug.*, 1951).

(24) **Metal refractory alloys.** W. G. LIDMAN and H. J. HAMJIAN. *Prod. Engng.*, **22**, 147-150 (*Oct.*, 1951).

MISCELLANEOUS

(25) **Woomera.** *Flight*, **59**, 429-431 (*April* 13, 1951).
Brief review of British rocket projects and description of facilities at Woomera.

(26) **Twenty years of rocket post.** CAP. *Weltraumfahrt* (3), 57-58 (*June*, 1951). (*In German.*)
The work of Schmiedl in Austria during the early thirties.

(27) **The Naval Air Rocket Test Station—purposes and progress.** F. C. DURANT. *J. Amer. Rocket Soc.* (85), 74-79 (*June*, 1951).

The function and existing and planned facilities are described. Details are given of various projects.

(28) **An International Institute for Astronautics.** G. LOESER. *Weltraumfahrt* (4), 74-77 (*Aug.*, 1951.) (*In German.*) Published in English in *J.B.I.S.*, **10**, 146-148 (*July*, 1951).

(29) **Pros and cons of experimentation in rocket societies.** L. J. GRANT. *J. Space Flight*, **3** (7), 1-4 (*Sept.*, 1951).

PHYSICS

(30) **Fluid flow through porous metals.** L. GREEN and P. DUWEZ. *J. Appl. Mech.*, **18**, 39-45 (*March*, 1951).

A method is outlined for correlating experimental data obtained in studies of the flow of gases and liquids through porous metals. The correlation is based on the suggestion that the pressure gradient attending the flow of a liquid through a porous medium can be expressed as a function of flow rate by a simple quadratic equation.

(31) **Emissivity calculations for diatomic gases.** S. S. PENNER. *J. Appl. Mech.*, **18**, 53-58 (*March*, 1951).

An approximate method for estimating radiant-heat transfer from gaseous emitters has been developed. The method is particularly useful for high-pressure combustion chambers. Representative emissivity calculations over a wide temperature range are described.

(32) **A two-path method for measuring flame temperatures and concentrations in low pressure combustion chambers.** S. S. PENNER. *J. Chem. Phys.*, **19**, 272-280 (*March*, 1951). (29 refs.)

(33) **Thermodynamic properties of reactive gas mixtures.** A. S. CAMPBELL. *J. Franklin Inst.*, **251**, 437-452 (*April*, 1951).

Shows that the comparative behaviour of fixed composition and chemical equilibrium, when compelled to undergo isentropic changes of state from the same initial point, depends first on the type of chemical reaction present. Chemical reactions are shown to fall into three classes, depending upon the algebraic sign of the product of the mole change and heat of reaction.

(34) **An accurately calculable case of the three-body problem.** W. SCHAUB. *Weltraumfahrt* (3), 61-66 (*June*, 1951). (*In German.*)

The case of three bodies in an equilateral triangle.

(35) **Evidence for ionosphere currents from rocket experiments near the geomagnetic equator.** E. MAPLE, W. A. BOWEN and S. F. SINGER. *Phys. Rev.*, **82**, 957-958 (*June* 15, 1951).

(36) **Approximate calculations of specific heats for polyatomic gases.** R. V. MEGHREBLIAN. *J. Amer. Rocket Soc.*, **21**, 127-128 (*Sept.*, 1951).

The method is based on the assignment of characteristic frequencies to individual interatomic bonds, the simplification consisting in the use of the same characteristic frequency for a particular bond irrespective of the over-all structure of the molecule in which it occurs. The method can be applied to molecules for which precise spectroscopic data are not available.

PROJECTILES

(37) **On the classification of rockets.** R. ENGEL *et al.*, *O.N.E.R.A., Paris*, 302 pp. (1950). (*In French and German.*)

Discusses methods of classification of the structure and propulsion systems, including proposed tables for recording properties of materials and propellants.

(38) **Sun follower for V-2 rockets.** H. L. CLARK. *Electronics*, **23**, 71-73 (*Oct.*, 1950).

A photocell-controlled servo-drive mechanism for keeping a spectrograph in a spinning V-2 pointed at the sun.

(39) **Rocket projectile.** E. F. CHANDLER. U.S. Pat. No. 2,524,591 (*Oct.* 3, 1950).

(40) **Multiple grain rocket for propelling underwater torpedoes.** R. W. WALLACE and W. E. COLBURN. U.S. Pat. No. 2,529,465 (*Nov.* 7, 1950).

(41) **Rocket.** C. N. MARI. U.S. Pat. No. 2,535,309 (*Dec.* 26, 1950).

(42) **Note on self-propulsion with a separate energy source.** M. P. BLANC. *Mem. Artill. Franc.*, **25,** 103-116 (1951). (*In French.*)

Treats the case of a rocket using an inert working fluid with a separate energy source, i.e. an atomic rocket. It is shown that for maximum performance the exhaust velocity must vary with the time of operation and that the absolute velocity of the exhaust gases must remain constant. Also the optimum mass ratio is about 5. A numerical example is given using uranium as a source of energy.

(43) **Ballistic perturbations of a solid-propellant rocket projectile during the propulsion phase.** P. CARRIÉRE. *Mem Artill. Franc.*, **25,** 253-360 (1951). (*In French.*)

The fact that the dispersion of solid-propellant rockets is greater than that of artillery shells is chiefly due to the propulsion phase. The major reasons are (1) effects of air turbulence, (2) excentric thrust and (3) initial impulse. The effect of variation of total impulse is not considered since this occurs also with conventional artillery. The various factors are dealt with theoretically and numerical cases are solved. By means of simplifications a suitable form of the theory is evolved for examination of individual cases and an example is given.

(44) **Apparatus for decelerating torpedoes.** W. R. SMYTHE. U.S. Pat. No. 2,539,643 (*Jan.* 30, 1951).

(45) **The perturbation calculus in missile ballistics.** R. DRENICK. *J. Franklin Inst.*, 251, 423-436 (*April*, 1951).

The calculus of perturbations is modified for application to rocket missiles. It is of considerable value in establishing analytically certain principles of guidance and control; two examples are given.

(46) **Exclusive pictures reveal Viking rate of roll 107 miles up.** *West. Flg.*, **31,** 20 (*May*, 1951).

Series of 19 pictures taken from the Viking rocket.

(47) **On the accuracy of the long-range ballistic rocket.** W. E. FRYE. *J. Appl. Phys.*, **22,** 585-589 (*May*, 1951).

The accuracy of a V-2 type ballistic rocket which is guided to the termination of propulsion and is in free flight thereafter is investigated. The effect of the rotation of the earth and the re-entry into the atmosphere on the accuracy is considered and the errors due to lack of thrust control are analysed.

(48) **Rocket researches.** *Aeroplane*, **80,** 600 (*May* 18, 1951).

Photos of work at N.A.C.A.

(49) **Launching apparatus for rocket craft.** R. H. GODDARD. U.S. Pat. No. 2,555,083 (*May* 29, 1951).

(50) **Auxiliary power for guided missiles.** *Aviation Wk.*, **54,** 32 (*June* 11, 1951).

(51) **Navy missiles production ordered.** *Aviation Wk.*, **54,** 14 (*June* 11, 1951).

(52) **Rockets for aircraft model tests.** *Weltraumfahrt* (4), 78-79 (*Aug.*, 1951). (*In German.*)

Rocket-propelled models of the Douglas D-558.

(53) **Star-tracking missiles.** J. G. STRONG. *Aeroplane*, **81,** 212-215 (*Aug.* 24, 1951).

Celestial-guidance is likely to be used only on winged missiles. The theory and description of a possible tracking mechanism is given.

(54) **Optimum thrust programming for a sounding rocket.** H. S. TSIEN and R. C. EVANS. *J. Amer. Rocket Soc.*, **21,** 99-107 (*Sept.*, 1951).

The problem of optimum thrust programming for a sounding rocket of minimum starting weight to reach a specified height with given fuel weight and propellant characteristics is first formulated as a problem in variational calculus. The general solution for arbitrary drag function is given. The solution is then applied to two special cases, one with quadratic drag dependence on velocity and the other with linear drag dependence. Complete numerical data are given. The results are then compared with the results of constant thrust to show the advantages of thrust programming. Thrust programming is shown to be able to increase appreciably the pay load of a high altitude sounding rocket.

ROCKET MOTORS

(55) **Steam production from cooling liquid in combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,526,219 (*Oct.* 17, 1950).

(56) **Spray nozzle.** R. H. GODDARD. U.S. Pat. No. 2,526,220 (*Oct.* 17, 1950).

(57) **Gas-operated apparatus for pumping very cold liquids.** R. H. GODDARD. U.S. Pat. No. 2,526,221 (*Oct.* 17, 1950).

(58) **Cooling and feeding means for rocket type combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,526,222 (*Oct.* 17, 1950).

(59) **Pressurized jacket construction for rotating combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,526,223 (*Oct.* 31, 1950).

(60) **Rotating combustion chamber with fixed jacket casing.** R. H. GODDARD. U.S. Pat. No. 2,526,224 (*Oct.* 31, 1950).

(61) **Circuit closing device for fuel feed apparatus and having quick-acting thermal control.** R. H. Goddard. U.S. Pat. No. 2,528,134 (*Oct.* 31, 1950).

(62) **Thermal jet and rocket motor propulsion system.** M. J. ZUCROW. U.S. Pat. No. 2,531,761 (*Nov.* 28, 1950).

(63) **Scavenging system for rocket motors utilizing liquid nitrogen.** R. H. GODDARD. U.S. Pat. No. 2,532,708 (*Dec.* 5, 1950).

(64) **Liquid cooled baffles between mixing and combination chambers.** R. H. GODDARD. U.S. Pat. No. 2,532,709 (*Dec.* 5, 1950).

(65) **Vapour generating and control apparatus for combustion chamber.** R. H. GODDARD. U.S. Pat. No. 2,532,710 (*Dec.* 5, 1950).

(66) **Expanded conical nozzle for two combustion liquids.** R. H. GODDARD. U.S. Pat. No. 2,532,711 (*Dec.* 5, 1950).

(67) **Vane structure for rotating combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,532,712 (*Dec.* 5, 1950).

(68) **Recoil-operated feeding apparatus for a combustion chamber used in aerial propulsion.** R. H. GODDARD. U.S. Pat. No. 2,536,597 (*Jan.* 2, 1951).

(69) **Premixing and fuel feeding arrangement for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,536,598 (*Jan.* 2, 1951).

(70) **Steam-operated rotating combustion chamber.** R. H. GODDARD. U.S. Pat. No. 2,536,599 (*Jan.* 2, 1951).

(71) **Rotating, feeding and cooling means for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,536,600 (*Jan.* 2, 1951).

(72) **Feed valve mechanism for rotating combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,536,601 (*Jan.* 2, 1951).

(73) **Mechanism for coaxial feeding of two combustion liquids to a combustion chamber.** R. H. GODDARD. U.S. Pat. No. 2,540,665 (*Feb.* 6, 1951).

(74) **Fuel feeding and premixing apparatus for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,540,666 (*Feb.* 6, 1951).

(75) **Driving means for rotating combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,544,418 (*March* 6, 1951).

(76) **Combustion chamber with wide-angle discharge for use in propulsion apparatus.** R. H. GODDARD. U.S. Pat. No. 2,544,419 (*March* 6, 1951).

(77) **Combustion chamber in rotating annular casing.** R. H. GODDARD. U.S. Pat. No. 2,544,420 (*March* 6, 1951).

(78) **Automatic control mechanism for gas storage tanks.** R. H. GODDARD. U.S. Pat. No. 2,544,421 (*March* 6, 1951).

(79) **Cooling means for a combustion chamber and nozzle in which solid fuel is burned.** R. H. GODDARD. U.S. Pat. No. 2,544,422 (*March* 6, 1951).

(80) **Liquid-sealing means between stationary and rotated parts.** R. H. GODDARD. U.S. Pat. No. 2,544,423 (*March* 6, 1951).

(81) **Revolving combustion chamber.** R. H. GODDARD. U.S. Pat. No. 2,551,111 (*May* 1, 1951).

(82) **Premixing combustion chamber.** R. H. GODDARD. U.S. Pat. No. 2,551,112 (*May* 1, 1951).

(83) **Liquid feeding mechanism for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,551,113 (*May* 1, 1951).

(84) **Two-liquid feeding device for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,551,114 (*May* 1, 1951).

(85) **Hollow partition between premixing and combustion chambers for rockets.** R. H. GODDARD. U.S. Pat. No. 2,551,115 (*May* 1, 1951).

(86) **Feeding and cooling means for continuously operated internal combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,555,080 (May 29, 1951).

(87) **Means for supplying liquids to an annular rotating combustion chamber.** R. H. GODDARD. U.S. Pat. No. 2,555,081 (*May* 29, 1951).

(88) **Liquid oxygen and fuel feeding apparatus utilizing oxygen for scavenging.** R. H. GODDARD. U.S. Pat. No. 2,555,082 (*May* 29, 1951).

(89) **Means for deflecting axial flow in a combustion chamber for propulsion apparatus.** R. H. GODDARD. U.S. Pat. No. 2,555,084 (*May* 29, 1951).

(90) **Two-liquid feeding reflecting device for combustion chambers in propulsion apparatus.** R. H. GODDARD. U.S. Pat. No. 2,555,085 (*May* 29, 1951).

(91) **Throttling thrust-chamber control.** M. MEYER. *J. Amer. Rocket Soc.* (85), 68-73 (*June*, 1951).

Covers the theory of throttling and describes methods of pump output control and variation of turbine power.

(92) **Expellant bags for rocket propellant tanks.** W. R. SHERIDAN. *J. Amer. Rocket Soc.* (85), 80-82 (*June*, 1951).

Material of bags must be thin and easily folded but not liable to tearing or bursting under sudden application of gas pressure or acceleration of missile. Examples of bags are given for various propellants and conditions.

(93) **Feeding apparatus, including injectors adapted to supply combustion liquids under pressure to a combustion chamber.** R. H. GODDARD. U.S. Pat. No. 2,558,483 (*June* 26, 1951).

(94) **Cooling jacket and heat-resistant cap for combustion chambers.** R. H. GODDARD. U.S. Pat. No. 2,558,484 (*June* 26, 1951).

(95) **Thermodynamics and chemical kinetics of one-dimensional non-viscous flow through a Laval nozzle.** S. S. PENNER. *J. Chem. Phys.*, **12,** 877-881 (*July*, 1951).

Explicit relations have been obtained for the enthalpy changes in one-dimensional, non-viscous flow through a Laval nozzle, where arbitrary deviations from thermodynamic equilibrium of chemical composition and of internal electronic, vibrational, or rotational energy states may occur.

(96) **Rocket motor technology highlights conference.** *Chem. Engng. News*, **29,** 2745-2746 (*July* 2, 1951).

Ceramics for uncooled motors and materials for hydrogen peroxide.

(97) **Determination of rocket-motor heat-transfer coefficients by the transient method.** S. GREENFIELD. *J. Aero. Sci.*, **18,** 512-518, 526 (*Aug.*, 1951).

The procedure utilizes the transient temperature rise of the uncooled segmented walls of a rocket motor to determine the rate of heat transfer. The method was used to determine axial variation of film heat-transfer coefficients of gases at temperatures up to 3,000° F. flowing through a de Laval type nozzle at rates typical of rocket-motor operation. Results of 107 tests are presented.

(98) **A theory of unstable combustion in liquid propellant rocket systems.** M. SUMMERFIELD. *J. Amer. Rocket Soc.*, **21,** 108-114 (*Sept.*, 1951).

On the basis of an hypothesis that low-frequency oscillations (chugging) sometimes observed in liquid propellant rocket engines, are the result of oscillatory propellant flow induced by a combustion time lag, conditions for the suppression of such oscillations are derived. It is found that stability can be achieved by increases in the length of feed line, the velocity of the propellant in the feed line, the ratio of feed pressure to chamber pressure, and the ratio of chamber volume to nozzle area. Equations are given for the frequencies of oscillation. Examination of the equation for stability indicates that self-igniting propellant combinations are likely to be more stable than non self-igniting systems.

ROCKET PROPELLANTS

(99) **Calculated thermochemical properties for hydrazine-hydrogen peroxide reaction at high pressures.** W. J. BARR and E. J. WILSON. *J. Chem. Phys.*, **19,** 470-473 (*April*, 1951).

A stoichiometric mixture of anhydrous hydrazine and hydrogen peroxide is evaluated in terms of the resultant equilibrium temperature-pressure-density relationship corresponding to chamber pressures over the range 10,000 to 185,000 p.s.i.

(100) **Chemical fuel still best for long-range rockets.** *Chem. Engng. News*, **29**, 2054 (*May* 21, 1951).

According to A. J. Nerad there is a possibility that atomic hydrogen may be "fixed" in some manner for use in rockets. Conventional solid and liquid propellants are also discussed.

(101) **The effect of solid particles in rocket exhausts.** N. J. BOWMAN. *J. Space Flight*, **3** (6), 1-15 (*June*, 1951).

It is shown that in the formation of solid crystals from simple molecules in rocket exhausts there are two factors which reduce the thrust obtained. One is the velocity redistribution effect whereby unagglomerated particles increase their velocity and agglomerated particles lose some or all of their velocity. The second is the loss of internal energy through vibration of the molecules in the crystal lattice but this is not so important as the velocity redistribution effect.

(102) **Measurement of the burning rate of liquid propellants.** C. W. TAIT, A. G. WHITTAKER and H. WILLIAMS. *J. Amer. Rocket Soc.* (85), 83-88 (*June*, 1951).

Describes the use of 7 mm. glass tubes to measure the burning rates of non-hypergols. Measurements with mixtures of 2-nitropropane and nitric acid showed that the burning rate increased with the 1·1 power of pressure over the pressure range from 200 to 1,000 p.s.i.a. and with the 4·3 power over the range from 1,000 to 2,000 p.s.i.a.

(103) **Rocket propellant performance and energy of the chemical bond.** P. F. WINTERNITZ and D. HORVITZ. *J. Amer. Rocket Soc.* (85), 51-67 (*June*, 1951).

Shows how performance can be calculated from knowledge of the bond energies of the propellants. Heat of combustion values thus calculated differ by not more than one per cent. from the experimental values.

(104) **Solid fuel.** J. A. GRAND and R. A. MILLER. U.S. Pat. No. 2,555,333 (*June 5*, 1951).

Nitroguanidine/guanidine nitrate mixture.

(105) **The application of ozone as an oxidant in rocket motors.** H. J. HOELZGEN. *Weltraumfahrt* (4), 89-91 (*Aug.*, 1951). (*In German.*)

(106) **The hypergolic reaction of dicyclopentadiene with white fuming nitric acid.** C. H. TRENT and N. J. ZUCROW. *J. Amer. Rocket Soc.*, **21**, 129-131 (*Sept.*, 1951).

Photographic studies indicate that a solid phase is formed prior to ignition and that the ignition of the propellant is propagated from the solid phase. The latter has been isolated. Although the identity of the solid phase remains unknown, characterization tests have indicated that it is a nitrated polymer containing the nitro group and the nitrate ester group.

REVIEW

The Exploration of Space

(By Arthur C. Clarke. Temple Press, Ltd., London, xiii + 198 pp.. 18 figs. and 15 plates by R. A. Smith and Leslie Carr. 12s. 6d. net.)

Little more than 18 months have passed since the appearance of Mr. Clarke's first book, *Interplanetary Flight*. Now with the presses still hot from this earlier work, the publishers have produced *The Exploration of Space*. The new publication written in the succinct lucid style which we naturally expect from Mr. Clarke, covers much the same ground as the previous work, but in a simple non-technical manner, thereby meeting the requirements of a much wider public.

The author begins in the traditional style with an historical introduction, but wisely refrains from going into great detail on this aspect of astronautics, which has been presented already in such exhaustive detail in Ley's *Rockets and Space Travel*. Following this brief introduction the author contrives, in five short chapters, to set out the elementary principles of rocketry and space flight dynamics resorting frequently to simple analogies in order to make

these principles clear to the lay reader. Having thus introduced the reader to the problems of flight to other worlds Mr. Clarke goes on to give recent views on the solutions of these problems. In a succession of brief chapters he deals with such matters as communication and navigation, life in the spaceship, the conditions on our Moon and the planets and the difficulties which may be encountered in setting up bases and colonies. Rather late in the text the author returns to the vicinity of the mother planet to consider the subject of orbital space stations. Then, perhaps, relenting this cowardly retreat from the interplanetary depths, he flashes outwards once again into the interstellar and intergalactic void. The book ends on a philosophical note with an examination of the significance of interplanetary exploration in human affairs.

Throughout the *Exploration of Space* a fairly high standard of technical accuracy is maintained; in this respect it differs from many other works on astronautics! Occasionally Mr. Clarke may offend the serious student of astronautics with a rather pontifical pronouncement on a matter which is open to considerable doubt. Many eyebrows will be raised for example, at the author's assertion that it "would be a vastly simpler task" to build really large telescopes on the Moon than on the Earth. Sometimes, too, the author appears to arrive at conclusions after having considered only half of the relevant arguments. Thus his justification of the "dumbell shape" for the interplanetary vehicle, particularly in the case of atomic propulsion, is clearly based on an incomplete examination of the problems involved. A more careful consideration of the shielding requirements which he mentions, would have shown that the dumbell arrangement is most unfavourable. Some comment might also be made on the author's failure to point out the disadvantages inherent in the technique of splitting the interplanetary voyage into "easy" stages. Indeed, the orbital technique is forced upon us by necessity rather than by choice, a fact which should have received greater stress.

Apart from these shortcomings, none of which could be called a serious technical fault, *The Exploration of Space* is singularly free from those questionable statements which, unfortunately, so often occur in books on space-flight. The reviewer is rather dubious about one or two points in the text however. For example, the method of fixing the position of a vehicle in space (p. 81) by measuring the two angles subtended at the spaceship by three solar bodies (Sun, Earth and Venus in this case) appears to be inadequate for a three dimensional fix. A better procedure would be to photograph two of the planets against the star fields and measure their angular co-ordinates on the celestial sphere. Another comparatively minor point concerns the statement (p. 135) that Jupiter might be gaseous right to the centre of the core. Clearly at the temperatures which have been observed over the surface of this planet it would not be possible for the common non-volatile constituents such as ammonia to remain in the gaseous state except in the outer tenuous layers.

So far we have considered only Mr. Clarke's contribution to the book. No less important to its success, however, are the very fine illustrations by Messrs. R. A. Smith and Leslie Carr, some of which may be compared not unfavourably with the much publicized Bonestells. Particular mention might be made of the following coloured plates:—"Automatic Rocket Surveying

Mars," "The Lunar Base" and the cover picture "A Multiple Sun System" (despite the highly suspicious spiral of gas—a feature which Mr. Clarke will be requested to explain in due course!) The reviewer's favourite black and white illustration is Plate II, "Spaceships Refuelling in Free Orbit," which conveys a dramatic picture of the orbital technique. Only one illustration calls for unfavourable comment and that is the painting of the Martian Base, the foreground of which might well be an aerial photograph of Southend-on-Sea.

The Exploration of Space will be enjoyed by all readers who are interested in astronautics. It is particularly recommended to those enthusiasts who gamely support our Society, but who find some of the material in the *B.I.S. Journal* "very heavy going." This is essentially their book.

L. R. S.

RECENT AND FORTHCOMING MEETINGS

July 25, 1951. "Rocket Propulsion and Interplanetary Flight," by A. V. Cleaver to St. Albans Rotary Club.

August 9, 1951. "Rocket Propulsion and Interplanetary Flight," by A. V. Cleaver to All Nations Social Club, Marble Arch, London, W.1.

August 28, 1951. "Interplanetary Travel and Rocketry," by G. V. E. Thompson, to the South-West London Branch of the Association of Scientific Workers, at Wandsworth Town Hall, Wandsworth, S.W.18, at 7 p.m.

September 26, 1951. "Interplanetary Travel and the Work of the British Interplanetary Society," by G. V. E. Thompson, to the Hornchurch Round Table (No. 255), at the Bell Hotel, Upminster, Essex, at 7.45 p.m.

September 27, 1951. "Rocket Propulsion and Interplanetary Flight," by A. V. Cleaver to Allied Circle, Green Street, London, W.1.

October 10, 1951. "Interplanetary Flight" by E. Burgess, Leigh Technical College Engineering Society, Leigh, Lancs.

October 12, 1951. "Interplanetary Flight," by L. J. Carter to the North-West Kent Discussion Group, County Grammar School for Girls, Sidcup, Kent, 7 p.m.

October 22, 1951. "Interplanetary Flight," by A. C. Clarke, at Bancroft School, Woodford Green, Essex.

October 30, 1951. Comments on "When Worlds Collide," from the stage of the Penge Odeon, by A. C. Clarke, at 7.30 p.m.

October 31, 1951. "The First Moon Rocket," by E. Burgess, Royal Aeronautical Society, Brough Branch, Electricity Showrooms, Ferensway, Hull, at 7 p.m.

November 1, 1951. "Interplanetary Flight," by E. Burgess, the Bury Round Table, Derby Hotel, Bury, at 7.30 p.m.

November 6, 1951. "The Exploration of Space," by A. C. Clarke, to the Cosmos Radio and Scientific Society, Edison Swan, Ltd., Brimsdown, Enfield, at 6 p.m.

November 9, 1951. "The Exploration of Space," by A. C. Clarke, to the Scientific Society, Reading University, at 7 p.m.

November 19. 1951. "Moonflight," by M. A. Browne to the Rotary Club of Oldham.

November 20, 1951. "Into Space," by E. Burgess, King George V School, Southport, Lancs., at 4.10 p.m.

November 20, 1951 (Tuesday). "Interplanetary Travel," by A. C. Clarke, to the Mathematical Society, King's College, London, at 5 p.m.

November 26, 1951. "Planets and Spaceships," by A. C. Clarke, to the Preston Astronomical Society, at 7.30 p.m.

November 26, 1951. "Rocket Propulsion and Interplanetary Flight," by A. V. Cleaver, to Nottingham Society of Engineers.

November 27, 1951. "Into Space," by E. Burgess, Society of Automotive Electrical Technicians, Engineers' Club, Albert Square, Manchester, 1, at 7.45 p.m.

November 28, 1951 (Wednesday). "Principles of Space Flight," by A. C. Clarke, to the Weybridge Branch, Royal Aeronautical Society, Vickers-Armstrong, Ltd., at 6 p.m.

December 7, 1951. "Rocket Propulsion and Interplanetary Flight," by A. V. Cleaver, to Perse School, Cambridge.

December 9, 1951. "Interplanetary Flight," by E. Burgess, Wilton Street Young People's League, Denton, 8.10 p.m.

December 12, 1951. "The Establishment and Use of Artificial Satellites," by E. Burgess to the Leeds Astronomical Society, Department of Physics, The University, Leeds, 7.15 p.m.

December 12, 1951. "The Engineering Aspects of Rocket Motor Development and Testing," by J. Humphries, to the Incorporated Plant Engineers, Nottingham, 7 p.m.

January 13, 1952. "Interplanetary Flight," by E. Burgess, Brookfield Young People's League, Gorton, Manchester, at 7 p.m.

January 17, 1952. "Interplanetary Flight," by E. Burgess, Denton Men's Club, Denton, Lancs., at 8 p.m.

February 1, 1952. "Interplanetary Flight," by E. Burgess, Public Lecture, Flixton Library, Brook Street, Flixton, Lancs., at 7 p.m.

February 2, 1952. "Problems of the First Moon Rocket," by E. Burgess, Derbyshire and Lancashire Gliding Club, Camphill, Gt. Hucklow, Derbyshire, at 7 p.m.

February 22, 1952. "Into Space," by E. Burgess, the Physical Society, George Holt Physics Laboratories, The University, Liverpool, at 5 p.m.

February 27, 1952. "Interplanetary Flight," by E. Burgess, the Holliday Fellowship, Geographical Hall, Parsonage, Manchester, at 7.30 p.m.

February 28, 1952. "Rockets and Space Travel," by J. Humphries to the R.Ae.S., Portsmouth Branch.

February 28, 1952. "Problems of the First Moon Rocket," by E. Burgess, Bury Round Table, Derby Hotel, Bury, 7.30 p.m.

February 29, 1952. "Rockets and Space Travel," by J. Humphries, to Monsanto Scientific Society, Ruabon, North Wales.

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